Rules and Regulations for the Classification of Mobile Offshore Units

Parts 1 to 8

June 2013

Lloyd's Register

LIFE MATTERS

Rules and Regulations for the Classification of Mobile Offshore Units

Part 1
Regulations

June 2013

Lloyd's Register

LIFE MATTERS

A guide to the Rules

and published requirements

Rules and Regulations for the Classification of Mobile Offshore Units

Introduction

The Rules are published as a complete set, individual Parts are, however, available on request. A comprehensive List of Contents is placed at the beginning of each Part.

Numbering and Cross-References

A decimal notation system has been adopted throughout. Five sets of digits cover the divisions, i.e. Part, Chapter, Section, sub-Section and paragraph. The textual cross-referencing within the text is as follows, although the right hand digits may be added or omitted depending on the degree of precision required:

(a) In same Chapter, e.g. *see* 2.1.3 (i.e. down to paragraph).
(b) In same Part but different Chapter, e.g. *see* Ch 3,2.1 (i.e. down to sub-Section).
(c) In another Part, e.g. *see* Pt 5, Ch 1,3 (i.e. down to Section).

The cross-referencing for Figures and Tables is as follows:

(a) In same Chapter, e.g. as shown in Fig. 2.3.5 (i.e. Chapter, Section and Figure Number).
(b) In same Part but different Chapter, e.g. as shown in Fig. 2.3.5 in Chapter 2.
(c) In another Part, e.g. *see* Table 2.7.1 in Pt 3, Ch 2.

Rules updating

The Rules are generally published annually and changed through a system of Notices. Subscribers are forwarded copies of such Notices when the Rules change.

Current changes to Rules that appeared in Notices are shown with a black rule alongside the amended paragraph on the left hand side. A solid black rule indicates amendments and a dotted black rule indicates corrigenda.

Rules programs

LR has developed a suite of Calculation Software that evaluates Requirements for Ship Rules, Special Service Craft Rules and Naval Ship Rules. For details of this software please contact LR.

June 2013

CLASSIFICATION OF MOBILE OFFSHORE UNITS

Rules and Regulations

June 2013

UPDATE NOTES

1. The July 2003 version of these Rules and Regulations incorporates those changes contained in the Notices to the September 1996 version.
2. Changes approved by the Board.
3. Editorial amendments have also been incorporated.
4. The June 2013 version of these Rules and Regulations supersedes the July 2003 version.

CLASSIFICATION

The following explanatory note is offered to assist those concerned in the application of these Rules and Regulations.

Explanatory Note

Unit classification may be regarded as the development and worldwide implementation of published Rules and Regulations which, in conjunction with proper care and conduct on the part of the Owner and operator, will provide for:

1. the structural strength of (and where necessary the watertight integrity of) all essential parts of the hull and its appendages;
2. the safety and reliability of the propulsion and steering systems; and
3. the effectiveness of those other features and auxiliary systems which have been built into the unit in order to establish and maintain basic conditions on board whereby appropriate cargoes and personnel can be safely carried whilst the unit is at sea, at anchor, or moored in harbour.

Lloyd's Register Group Limited (LR) maintains these provisions by way of the periodical visits by its Surveyors to the unit as defined in the Regulations in order to ascertain that the vessel currently complies with those Rules and Regulations. Should significant defects become apparent or damages be sustained between the relevant visits by the Surveyors, the Owner and operator are required to inform LR without delay. Similarly any modification which would affect Class must receive prior approval by LR.

A unit is said to be in Class when the Rules and Regulations which pertain to it have, in the opinion of LR, been complied with, or when special dispensation from compliance has been granted by LR.

It should be appreciated that, in general, classification Rules and Regulations do not cover such matters as the unit's floatational stability, life-saving appliances, pollution prevention arrangements, and structural fire protection, detection and extinction arrangements where these are covered by the *International Convention for the Safety of Life at Sea, 1974*, its Protocol of 1978, and the amendments thereto, nor do they protect personnel on board from dangers connected with their own actions or movement around the unit. This is because the handling of these aspects is the prerogative of the National Authority with which the unit is registered. A great many of these authorities, however, delegate such responsibilities to the Classification Societies who then undertake them in accordance with agreed procedures.

Chapter Contents Part 1

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■ *Section 1*

1.1 Lloyd's Register Group Limited is a registered company under English law, with origins dating from 1760. It was established for the purpose of producing a faithful and accurate classification of merchant shipping. It now primarily produces classification Rules.

1.2 Classification services are delivered to clients by a number of other members subsidiaries and affiliates of Lloyd's Register Group Limited, including but not limited to: Lloyd's Register EMEA, Lloyd's Register Asia, Lloyd's Register North America, Inc., and Lloyd's Register Central and South America Limited. Lloyd's Register Group Limited, its subsidiaries and affiliates are hereinafter, individually and collectively, referred to as 'LR'.

■ *Section 2*

2.1 Lloyd's Register Group Limited is managed by a Board of Directors (hereinafter referred to as 'the Board').

The Board has:

appointed a Classification Committee and determined its powers and functions and authorised it to delegate certain of its powers to a Classification Executive and Devolved Classification Executives;
appointed Technical Committees and determined their powers, functions and duties.

2.2 LR has established National and Area Committees in the following:

Countries:
Australia (via Lloyd's Register Asia)
Canada (via Lloyd's Register North America, Inc.)
China (via Lloyd's Register Asia)
Egypt (via Lloyd's Register EMEA)
Federal Republic of Germany
(via Lloyd's Register EMEA)
France (via Lloyd's Register EMEA)
Italy (via Lloyd's Register EMEA)
Japan (via Lloyd's Register Group Limited)
New Zealand (via Lloyd's Register Asia)
Poland (via Lloyd's Register (Polska) Sp zoo)
Spain (via Lloyd's Register EMEA)
United States of America (via Lloyd's Register North America, Inc.)

Areas:
Benelux (via Lloyd's Register EMEA)
Central America (via Lloyd's Register Central and South America Ltd)
Nordic Countries (via Lloyd's Register EMEA)
South Asia (via Lloyd's Register Asia)
Asian Shipowners (via Lloyd's Register Asia)
Greece (via Lloyd's Register EMEA)

■ *Section 3*

3.1 LR's Technical Committee is at present composed of a maximum of 80 members which includes:

Ex officio members:

• Chairman and Chief Executive Officer of Lloyd's Register Group Limited	
• Chairman of the Classification Committee of Lloyd's Register Group Limited	

Members Nominated by:

• Technical Committee	
• Royal Institution of Naval Architects	2
• Institution of Engineers and Shipbuilders in Scotland	2
• Institute of Marine, Engineering, Science and Technology	2
• Institute of Materials, Minerals and Mining	1
• Honourable Company of Master Mariners	2
• Institution of Engineering and Technology	1
• Institute of Refrigeration	1
• Welding Institute	1
• Shipbuilders' and Shiprepairers' Association	2
• The Society of Consulting Marine Engineers and Ship Surveyors	1
• Community of European Shipyards Associations	1
• Society of Maritime Industries	2
• European Marine Equipment Council	1
• Chamber of Shipping	1
• Greek Shipping Co-operation Committee	1
• International Association of Oil and Gas Producers	1

3.2 In addition to the foregoing:

(a) Each National or Area Committee may appoint a representative to attend meetings of the Technical Committee.

(b) A maximum of five representatives from National Administrations may be co-opted to serve on the Technical Committee. Representatives from National Administrations may also be elected as members of the Technical Committee under one of the categories identified in 3.1.

(c) Further persons may be co-opted to serve on the Technical Committee by the Technical Committee.

3.3 All elections are subject to confirmation by the Board.

3.4 The function of the Technical Committee is to consider:

(a) any technical issues connected with LR's marine business;

(b) any proposed alterations in the existing Rules;

(c) any new Rules for classification;

Where changes to the Rules are necessitated by mandatory implementation of International Conventions, Codes or Unified Requirements adopted by the International Association of Classification Societies these may be implemented by LR without consideration by the Technical Committee.

3.5 The term of office of the Chairman and of all members of the Technical Committee is five years. Members may be re-elected to serve an additional term of office with the approval of the Board. The term of office of the Chairman may be extended with the approval of the Board.

3.6 In the case of continuous non-attendance of a member, the Technical Committee may withdraw membership.

3.7 Meetings of the Technical Committee are convened as often and at such times and places as is necessary, but there is to be at least one meeting in each year. Urgent matters may be considered by the Technical Committee by correspondence.

3.8 Any proposal involving any alteration in, or addition to, Part 1, Chapter 1 of Rules for Classification is subject to approval of the Board. All other proposals for additions to or alterations to the Rules for Classification other than Part 1, Chapter 1, will following consideration and approval by the Technical Committee either at a meeting of the Technical Committee or by correspondence, be recommended to the Board for adoption.

3.9 The Technical Committee is empowered to:

(a) appoint sub-Committees or panels; and

(b) co-opt to the Technical Committee, or to its sub-Committees or panels, representatives of any organisation or industry or private individuals for the purpose of considering any particular problem.

Section 4

4.1 LR's Naval Ship Technical Committee is at present composed of a maximum of 50 members and includes:
Ex officio members
- Chairman and Chief Executive Officer of Lloyd's Register Group Limited

Member nominated by:
- Naval Ship Technical Committee;
- The Royal Navy and the UK Ministry of Defence;
- UK Shipbuilders, Ship Repairers and Defence Industry;
- Overseas Navies, Governments and Governmental Agencies;
- Overseas Shipbuilders, Ship Repairers and Defence Industries;

4.2 All elections are subject to confirmation by the Board.

4.3 All members of the Naval Ship Technical Committee are to hold security clearance from their National Authority for the equivalent of NATO CONFIDENTIAL. All material is to be handled in accordance with NATO Regulations or, for non-NATO countries, an approved equivalent. No classified material shall be disclosed to any third party without the consent of the originator.

4.4 The term of office of the Naval Ship Technical Committee Chairman and of all members of the Naval Ship Technical Committee Chairman is five years. Members may be re-elected to serve an additional term of office with the approval of the Board. The term of the Chairman may be extended with the approval of the Board.

4.5 In the case of continuous non-attendance of a member, the Naval Ship Technical Committee may withdraw membership.

4.6 The function of the Naval Ship Technical Committee is to consider technical issues connected with Naval Ship matters and to approve proposals for new Naval Ship Rules, or amendments to existing Naval Ship Rules.

4.7 Meetings of the Naval Ship Technical Committee are convened as necessary but there will be at least one meeting per year. Urgent matters may be considered by the Naval Ship Technical Committee by correspondence.

4.8 Any proposal involving any alteration in, or addition to, Part 1, Chapter 1 of Rules for Classification of Naval Ships is subject to approval of the Board. All other proposals for additions to or alterations to the Rules for Classification of Naval Ships, other than Part 1, Chapter 1, will following consideration and approval by the Naval Ship Technical Committee, either at a meeting of the Naval Ship Technical Committee or by correspondence, be recommended to the Board for adoption.

4.9 The Naval Ship Technical Committee is empowered to:
(a) appoint sub-Committees or panels; and
(b) co-opt to the Naval Ship Technical Committee, or to its sub-Committees or panels, representatives of any organisation or industry or private individuals for the purpose of considering any particular problem.

Section 5

5.1 LR has the power to adopt, and publish as deemed necessary, Rules relating to classification and has (in relation thereto) provided the following:
(a) Except in the case of a special directive by the Board, no new Regulation or alteration to any existing Regulation relating to classification or to class notations is to be applied to existing ships.
(b) Except in the case of a special directive by the Board, or where changes necessitated by mandatory implementation of International Conventions, Codes or Unified Requirements adopted by the International Association of Classification Societies are concerned, no new Rule or alteration in any existing Rule is to be applied compulsorily after the date on which the contract between the ship builder and shipowner for construction of the ship has been signed, nor within six months of its adoption. The date of 'contract for construction' of a ship is the date on which the contract to build the ship is signed between the prospective shipowner and the ship builder. This date and the construction number (i.e. hull numbers) of all the vessels included in the contract are to be declared by the party applying for the assignment of class to a newbuilding. The date of 'contract for construction' of a series of sister ships, including specified optional ships for which the option is ultimately exercised, is the date on which the contract to build the series is signed between the prospective shipowner and the ship builder. In this section a 'series of sister ships' is a series of ships built to the same approved plans for classification purposes, under a single contract for construction. The optional ships will be considered part of the same series of sister ships if the option is exercised not later than 1 year after the contract to build the series was signed. If a contract for construction is later amended to include additional ships or additional options, the date of 'contract for construction' for such ships is the

date on which the amendment to the contract is signed between the prospective shipowner and the ship builder. The amendment to the contract is to be considered as a 'new contract'. If a contract for construction is amended to change the ship type, the date of 'contract for construction' of this modified vessel, or vessels, is the date on which the revised contract or new contract is signed between the Owner, or Owners, and the shipbuilder. Where it is desired to use existing approved ship or machinery plans for a new contract, written application is to be made to LR. Sister ships may have minor design alterations provided that such alterations do not affect matters related to classification, or if the alterations are subject to classification requirements, these alterations are to comply with the classification requirements in effect on the date on which the alterations are contracted between the prospective owner and the ship builder or, in the absence of the alteration contract, comply with the classification requirements in effect on the date on which the alterations are submitted to LR for approval.

(c) All reports of survey are to be made by surveyors authorised by members of the LR Group to survey and report (hereinafter referred to as 'the Surveyors') according to the form prescribed, and submitted for the consideration of the Classification Committee.

(d) Information contained in the reports of classification and statutory surveys will be made available to the relevant owner, National Administration, Port State Administration, P&I Club, hull underwriter and, if authorised in writing by that owner, to any other person or organisation.

(e) Notwithstanding the general duty of confidentiality owed by LR to its client in accordance with the LR Rules, LR clients hereby accept that, LR will participate in the IACS Early Warning System which requires each IACS member to provide its fellow IACS members and Associates with relevant technical information on serious hull structural and engineering systems failures, as defined in the IACS Early Warning System (but not including any drawings relating to the ship which may be the specific property of another party), to enable such useful information to be shared and utilised to facilitate the proper working of the IACS Early Warning System LR will provide its client with written details of such information upon sending the same to IACS Members and Associates.

(f) Information relating to the status of classification and statutory surveys and suspensions/withdrawals of class together with any associated conditions of class will be made available as required by applicable legislation or court order.

(g) A Classification Executive consisting of senior members of LR's Classification Department staff shall carry out whatever duties that may be within the function of the Classification Committee that the Classification Committee assigns to it.

■ *Section 6*

6.1 No LR Group employee is permitted under any circumstances, to accept, directly or indirectly, from any person, firm or company, with whom the work of the employee brings the employee into contact, any present, bonus, entertainment or honorarium of any sort whatsoever which is of more than nominal value or which might be construed to exceed customary courtesy extended in accordance with accepted ethical business standards.

■ *Section 7*

7.1 LR has the power to withhold or, if already granted, to suspend or withdraw any ship from class (or to withhold any certificate or report in any other case), in the event of non-payment of any fee to any member of the LR Group.

■ *Section 8*

8.1 When providing services LR does not assess compliance with any standard other than the applicable LR Rules, international conventions and other standards agreed in writing.

8.2 In providing services, information or advice, LR does not warrant the accuracy of any information or advice supplied. Except as set out herein, LR will not be liable for any loss, damage or expense sustained by any person and caused by any act, omission, error, negligence or strict liability of LR or caused by any inaccuracy in any information or advice given in any way by or on behalf of LR even if held to amount to a breach of warranty. Nevertheless, if the Client uses LR services or relies on any information or advice given by or on behalf of LR and as a result suffers loss, damage or expense that is proved to have been caused by any negligent act, omission or error of LR or any negligent inaccuracy in information or advice given by or on behalf of LR then LR will pay compensation to the client for its proved loss up to but not exceeding the amount of the fee (if any) charged for that particular service, information or advice.

8.3 LR will print on all certificates and reports the following notice: Lloyd's Register Group Limited, its affiliates and subsidiaries and their respective officers, employees or agents are, individually and collectively, referred to in this clause as ‘Lloyd's Register’. Lloyd's Register assumes no responsibility and shall not be liable to any person for any loss, damage or expense caused by reliance on the information or advice in this document or howsoever provided, unless that person has signed a contract with the relevant Lloyd's Register entity for the provision of this information or advice and in that case any responsibility or liability is exclusively on the terms and conditions set out in that contract.

8.4 Except in the circumstances of section 8.2 above, LR will not be liable for any loss of profit, loss of contract, loss of use or any indirect or consequential loss, damage or expense sustained by any person caused by any act, omission or error or caused by any inaccuracy in any information or advice given in any way by or on behalf of LR even if held to amount to a breach of warranty.

8.5 Any dispute about LR services is subject to the exclusive jurisdiction of the English courts and will be governed by English law.

Section

■ *Section 1* Conditions for classification

1.1 General

1.1.1 Units referred to in this Chapter are defined in Section 2 and Part 3.
Machinery referred to in this Chapter is defined in Parts 5 and 6.
Safety systems, hazardous areas and fire safety referred to in this Chapter are defined in Part 7.
Drilling and process plant referred to in this Chapter are defined in Pt 3, Ch 7 and Ch 8.
Materials referred to in this Chapter are defined in the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

1.1.2 Mobile offshore units built in accordance with LR's Rules and Regulations, or in accordance with requirements equivalent thereto, will be assigned a class on the *ClassDirect Live* website and will continue to be classed so long as they are found, upon examination at the prescribed surveys, to be maintained in accordance with the requirements of the Rules. Classification will be conditional upon compliance with LR's requirements for materials, structure, machinery, equipment and other safety considerations.

1.1.3 Units designed and constructed to standards other than the Rule requirements will be considered for classification, subject to the alternative standards being considered by LR to give an equivalent level of safety to the Rule requirements. It is essential that in such cases LR is informed of the Owner's proposals at an early stage, in order that a basis for acceptance of the standards may be agreed.

1.1.4 The Classification Committee, in addition to requiring compliance with LR's Rules, or other agreed performance standards, may require to be satisfied that units are suitable for geographical or other limits or conditions of the service contemplated.

1.1.5 Although the specified design environmental criteria on which classification is based are the responsibility of the Builders/designers, assessment by LR of a unit's suitability for service in a particular sea area will be undertaken and agreed before approval.

1.1.6 Loading conditions and other preparations required to permit a unit (whether self-propelled or not) with a notation specifying some service limitation to undertake a sea-going voyage, either from port of building to service area or from one service area to another, are to be in accordance with arrangements agreed by LR prior to the voyage.

1.1.7 Any damage, defect, breakdown or grounding, serious deficiency, detention or arrest, or refusal of access which could invalidate the conditions for which class has been assigned is to be reported to LR without delay.

1.1.8 The Owner is solely responsible for the operation of the unit. The Rules are framed on the understanding that the unit will be properly loaded and operated, and the environmental conditions are no more severe than those agreed for the design basis and approval, without prior agreement of LR.

1.1.9 When longitudinal strength calculations are required for surface type units, loading guidance information is to be supplied to the Master by means of a Loading Manual and in addition, when required, by means of a loading instrument, *see also* 1.1.10. Loading Manuals and loading instruments for surface type units are to be in accordance with Pt 3, Ch 4,8 of LR's *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships).

1.1.10 It will be the responsibility of the Owner to provide instructions and set down limits for the operation of the unit to ensure that the loading and environmental conditions on which classification is based will not be exceeded. These instructions and limitations are to be contained in the Operations Manual (or a Loading Manual for surface type units) which is to be retained on board the unit. The Owner should ensure that the Manual is kept up to date and contains appropriate data required by the relevant National Administration.

1.1.11 The adequacy of sea bed conditions with respect to bearing capacity, resistance to possible sliding and anchor holding capacity is not covered by classification. In particular, for self-elevating units, it is the responsibility of the Owner to be satisfied that the sea bed conditions are suitable to allow the legs to be safely and adequately preloaded.

1.1.12 For units, the arrangements and equipment of which are required to comply with the requirements of the:

- *IMO Code for the Construction and Equipment of Mobile Offshore Drilling Units, 2009* (2009 MODU Code);
- *Load Lines Convention*;
- *International Convention for the Safety of Life at Sea, 1974* and its Protocol of 1978;
- *International Convention for the Prevention of Pollution from Ships, 1973*, as modified by the Protocol of 1978 relating thereto;

- *International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk* (IBC Code); and applicable Amendments thereto.

  The Classification Committee requires the applicable Convention Certificates to be issued by a National Administration, or by LR, or by an IACS Member when so authorised. Safety Management Certificates in accordance with the provisions of the International Safety Management Code (ISM Code) may be issued by an organisation complying with IMO Resolution A.739(18) and authorised by the National Administration with which the unit is registered. Cargo Ship Radio Certificates may be issued by an organisation authorised by the National Administration with which the unit is registered. In the case of dual classed units, Convention Certificates may be issued by the other Society with which the unit is classed, provided that this is recognised in a formal Dual Class Agreement with LR and provided that the other Society is also authorised by the National Administration. In the event of a National Administration withdrawing any unit's Convention Certificate (referred to in this Section), then the Classification Committee may suspend the unit's class. If a unit is removed from the National Administration's Registry for non-compliance with the Conventions or Classification requirements referred to herein then the Classification Committee will suspend the unit's class. In the event of ISM Code certification being withdrawn from a unit or Operator, the Classification Committee will suspend the unit's class.

1.1.13 It is the Owner's responsibility to comply with any applicable regulations of the Coastal State Authorities in the areas of operation. Compliance with the prescribed standards of the applicable National Administration is to be demonstrated by the issue of appropriate certification by the National Administration or LR where so authorised. *See also* 1.1.14.

1.1.14 Where the National Administration has no prescribed standards for mobile offshore units which are outside the scope of application of the 2009 MODU Code and/or the International Conventions referred to in 1.1.12 or their standards are not considered acceptable for classification purposes, LR will apply the relevant parts of the 2009 MODU Code/Convention Regulations and other recognised Standards as applicable to the intended use of the unit as a prerequisite to classification.

1.1.15 Where an onboard computer system having longitudinal strength computation capability, which is required by the Rules, is provided on a new unit or newly installed on an existing unit, then the system is to be certified in respect of longitudinal strength in accordance with LR's *Approval of Longitudinal Strength and Stability Calculation Programs*.

1.1.16 Where an onboard computer system having stability computation capability is provided on a new unit, the system is to be certified in respect of stability aspects, in accordance with LR's *Approval of Longitudinal Strength and Stability Calculation Programs*. When provided, an onboard computer system having stability computation capability is to carry out the calculations and checks necessary to assess compliance with all the stability requirements applicable to the unit on which it is installed.

1.1.17 When accommodation and other support units are intended to operate for prolonged periods adjacent to other offshore installations which are being used for hydrocarbon exploration or production, it is the Owner's responsibility to comply with the requirements of the appropriate National Administration and LR is to be advised at the approval stage so that classification aspects relating to safety are taken into account, *see* Part 7. Special consideration will be given to existing units with regard to class.

1.1.18 Floating production and oil storage units which operate permanently at a fixed geographic location (including disconnectable units) will have class assigned in accordance with LR's *Rules and Regulations for the Classification of a Floating Offshore Installation at a Fixed Location*. *See also* Pt 3, Ch 1,1.1.3 and Ch 3,1.1.2.

1.1.19 When a unit, fitted with a conventional rudder, is to operate for a prolonged period at a fixed location, it is the Owner's responsibility to ensure that suitable arrangements are provided to prevent damage to the steering gear. Special consideration will be given to the requirements for the steering gear and propelling machinery, *see* Pt 4, Ch 10, and Pt 5, Ch 19 and Ch 6.

1.1.20 Where a unit has been detained by Port State Control, the Owner is to advise LR immediately, in order to arrange the attendance of a Surveyor.

1.2 Interpretation of the Rules

1.2.1 The interpretation of the Rules is the sole responsibility, and is at the sole discretion, of LR. Any uncertainty in the meaning of the Rules is to be referred to LR for clarification.

1.2.2 In many instances, these Rules require that particular components, systems and equipment, etc., must also comply with applicable Sections of the Rules for Ships. Every effort has been made to avoid potential conflicting requirements; however, where such a conflict becomes apparent, the requirements of these Rules shall take precedence.

1.2.3 Except in the case of a special directive by the Classification Committee, no new Rule or alteration in any existing Rule materially affecting classification is to be applied compulsorily within six months of its adoption, nor after the approval of the original midship section or equivalent original structural plans. Where it is desired to use existing previously approved plans for a new contract, written application is to be made to the Classification Committee.

1.3 Advisory services

1.3.1 The Rules do not cover certain technical characteristics, such as stability, hull vibration, etc., but advice may be given on such matters without any assumption of responsibility for such advice.

1.4 Legislative verification

1.4.1 LR has been authorised by a number of National Administrations to carry out verification of offshore units and installations in accordance with statutory Regulations. Full details will be supplied to Owners and other interested parties on request. *See also* 2.7 and Chapter 4.

1.4.2 LR has also been authorised on behalf of National Administrations of a large number of nations to issue certain statutory, safety and other certificates. LR is willing to act, when requested, in respect of such certification.

1.4.3 When machinery and equipment are to comply with EC Directives, LR as a notified body can issue EC Type Certification in accordance with LR's appointment. Full details will be supplied to manufacturers and other interested parties on request.

■ *Section 2*
Definitions, character of classification and class notations

2.1 General definitions

NOTE
For the purpose of class notations, the definitions given in 2.1.1 to 2.1.20 will apply.

2.1.1 **Offshore unit** means a unit engaged in offshore operations including drilling, oil production, accommodation and other support functions and which generally operates within the territorial waters of a flag state, but excluding the ship types defined in Part 4 of the Rules for Ships.

2.1.2 **Mobile** indicates that the unit is designed to be moved from one operating site to another.

2.1.3 **Coastal State Authority** is the Authority responsible for the safety standards of units operating in or adjacent to their territorial waters.

2.1.4 **National Authority** is the Marine Authority in the country in which a unit is registered.

2.1.5 **National Administrations** are those Authorities defined in 2.1.3 and 2.1.4.

2.1.6 **Owner**. In the context of these Rules, the Owner is defined as the party responsible for the unit, including its operation and safety.

2.1.7 **Self-propelled** means that the unit is designed for unassisted sea passages and is fitted with propelling machinery in accordance with LR Rules.

2.1.8 **Surface type units** are units with a ship or barge-type displacement hull of single or multiple hull construction intended for operation in the floating condition.

2.1.9 **Ship units** are self-propelled surface type units of shipshaped single or multiple hull form.

2.1.10 **Barge units** are surface type units without primary propelling machinery.

2.1.11 **Self-elevating units** are mobile units which are designed to operate as sea bed-stabilised units in an elevated mode. These units have a buoyant hull with movable legs capable of raising the hull above the surface of the sea. The legs may be designed to penetrate the sea bed, or be attached to a mat or individual footings which rest on the sea bed. *See also* 1.1.10.

2.1.12 **Semi-submersible or column-stabilised units** have working platforms supported on widely spaced buoyant columns. The columns are normally attached to buoyant lower hulls or pontoons. These units are normally floating types but can be designed to rest on the sea bed, *see also* 2.2.3.

2.1.13 **Support units** are units whose primary function is to support offshore installations. They are normally engaged in one or more of the following functions:

- crane operations, fire-fighting, diving operations, maintenance, construction, pipelaying and accommodation.

2.1.14 **Accommodation unit** is a support unit whose primary function is to provide accommodation for more than twelve offshore personnel who are not crew members or passengers.

2.1.15 **Support vessel**. Alternative name for a support unit as defined in 2.1.13.

2.1.16 **Positional mooring**. Station-keeping by means of multi-leg mooring systems with or without thruster assistance.
NOTE
Other definitions for mooring facilities are contained in Pt 3, Ch 10.

2.1.17 **Clear water**. Water having sufficient depth to permit the normal development of wind generated waves.

2.1.18 **Fetch**. The extent of clear water across which a wind has blown before reaching the unit.

2.1.19 **Sheltered water**. Water where the fetch is six nautical miles or less.

2.1.20 **Reasonable weather**. Wind strengths of force six or less in the Beaufort scale, associated with sea states sufficiently moderate to ensure that green water is taken on board the unit's weather deck at infrequent intervals only, or not at all.

2.2 Modes of operation

2.2.1 A mode of operation is a condition or manner in which a unit may operate or function while on location or in transit. From the classification aspect, the modes of operation of a unit should include the following:

(a) **Operating condition**
The condition when a unit is on location, for the purpose of carrying out its primary design operations, and the combined environmental and operational loadings are within the appropriate design limits established for such operations. The unit may be either afloat or supported on the sea bed, as applicable.

(b) **Survival condition**
A severe storm condition during which a unit may be subjected to the most severe environmental loadings for which the unit is designed. Drilling or similar operations may have been discontinued due to the severity of the environmental loadings. The unit may be either afloat or supported on the sea bed, as applicable.

(c) **Transit condition**
All unit movements from one geographical location to another.

NOTE
For surface type units, the mode of operation will be defined by the loading conditions stated in the approved loading manual.

2.2.2 **Linked** means connected while operating to a single point mooring facility, fixed structure or otherwise attached or resting on the sea bed.

2.2.3 **Sea bed-stabilised** means designed to operate under normal operating and survival conditions while the footings, mat or pontoons rest on the sea bed.

2.3 Character symbols

2.3.1 All units, when classed, will be assigned one or more character symbols, as applicable. For the majority of units, the character assigned will be **✠OU 100A1** or **✠OU 100AT**. *See also* 1.1.18.

2.3.2 A full list of character symbols for which offshore units may be eligible is as follows:

✠ This distinguishing mark will be assigned, at the time of classing, to new units constructed under LR's Special Survey, in compliance with the Rules, and to the satisfaction of the Classification Committee.

✠̄ This distinguishing mark will be assigned, at the time of classing, to new units constructed under LR's Special Survey, in accordance with plans approved by another recognised classification society.

OU These character letters will be assigned to all units which have been built or accepted into Class in accordance with LR's *Rules and Regulations for the Classification of Mobile Offshore Units*.

100 This character figure will be assigned to all units considered suitable for operating at exposed locations offshore or for sea-going service.

A This character letter will be assigned to all units which have been built or accepted into class in accordance with LR's Rules and Regulations, and which are maintained in good and efficient condition.

1 This character figure will be assigned to:

(a) Units having on board, in good and efficient condition, anchoring and/or mooring equipment in accordance with Pt 4, Ch 9 of the Rules.

(b) Units classed for special service, having on board, in good and efficient condition, anchoring and/or mooring equipment approved by the Classification Committee as suitable and sufficient for the particular service.

(c) Units equipped with a classed dynamic positioning system which has sufficient power, redundancy of components and duplication of controls to supplement or replace the anchoring equipment on board such that the combined system/equipment is approved by the Classification Committee as equivalent to the anchoring equipment necessary during voyages, transfer moves or under normal operating conditions, *see* Pt 3, Ch 9.

T This character letter will be assigned to units which are intended to perform their primary designed service function only while they are anchored, moored or linked, and which have, in good and efficient condition, adequately attached anchoring, mooring or linking equipment which has been approved by the Classification Committee as suitable and sufficient for the intended service.

N This character letter will be assigned to installations on which the Classification Committee has agreed that anchoring and mooring equipment need not be fitted in view of their particular service.

2.3.3 For classification purposes the character figure **1** or the character letter **T** is generally to be assigned, *see also* 2.3.5.

2.3.4 Non-propelled units assigned the character letter **T** which are required to make transit voyages from one operating site to another are to be fitted with towing arrangements in accordance with Pt 4, Ch 9.

2.3.5 When a self-propelled unit which normally performs its primary designed service function only while anchored, moored or linked is required by the Owners to make transit voyages from one operating site to another, the unit is to be fitted with anchoring equipment in accordance with the Rules, and the character figure (**1**) will be assigned after the character letter **T**.

2.3.6 In cases where the anchoring and/or mooring equipment is found to be seriously deficient in quality or quantity, the class of the unit will be liable to be withheld.

2.3.7 The character figure **100** will be omitted for units operating in protected waters such as harbours, inland lakes, etc., and the requirements of the Rules may be relaxed or otherwise amended as considered appropriate by the Classification Committee.

2.3.8 Units will not be classed unless the primary propelling machinery and/or the essential auxiliary machinery of the unit is also classed.

2.4 Class notations (hull/structure)

2.4.1 When considered necessary by the Classification Committee, or when requested by an Owner and agreed by the Classification Committee, a class notation will be appended to the character of classification assigned to the unit. This class notation will consist of one of, or a combination of, the following:

- A type notation.
- A special features notation.
- A special duties notation.
- A service restriction notation.
- An operating limits notation.

2.4.2 **Type notation**. A notation indicating that the unit has been arranged and constructed in compliance with the particular Rules intended to apply to that type of unit, e.g., Mobile drilling unit. Typical type notations are defined in Part 3.

2.4.3 **Special duties notation**. A notation indicating that the unit has been designed, modified or arranged for special duties other than those implied by the type notation, e.g., oil exploration. Units with special duties notations are not thereby prevented from performing any other duties for which they may be suitable.

2.4.4 **Special features notation**. A notation indicating that the unit incorporates special features which significantly affect the design, e.g., **DRILL**. *See* 2.4.13.

2.4.5 **Operating limits notation**. A notation indicating the significant design criteria on which approval of the unit is based, e.g.:

- Maximum operating environmental design limits for semi-submersible units and self-elevating units.
- Limiting sea state and/or wind speed during which a unit may remain moored to a single point mooring.

2.4.6 **Service restriction notation**. A notation indicating that the unit has been classed on the understanding that it will be operated only in suitable areas or conditions which have been agreed by the Classification Committee, e.g., protected waters service.

2.4.7 Service restriction notations will generally be assigned in the form shown in 2.4.9 and 2.4.10, but this does not preclude Owners requesting special consideration for other forms in unusual cases.

2.4.8 Where a service notation is applicable, certain exemptions may be granted. Where these affect statutory requirements, such as Load Lines, the Owner or Shipbuilder is to obtain the authorisation of the Flag State. Such exemptions are to be recorded on the Class certificate and any applicable statutory certificate.

2.4.9 **Protected waters service**. Service in sheltered water adjacent to sand banks, reefs, breakwaters or other coastal features.

2.4.10 **Specified operating area service**. Service within a defined geographical area which will be indicated on the *ClassDirect Live* website, e.g., Black Sea service.

2.4.11 A typical example of character of classification and class notations is:

✠**OU 100A1** Mobile drilling unit, **DRILL**, Oil exploration, Gulf of Mexico service.

2.4.12 The assigned character symbols of class and the appropriate class notations will be entered in the *ClassDirect Live* website. For all unit types except surface type units, the limiting structural design criteria on which classification is based will also be entered on the *ClassDirect Live* website.

2.4.13 The following special features class notations may be assigned as considered appropriate by the Classification Committee:

PPF This notation will be assigned to units which have specialised structures and an installed process plant facility which has been constructed, installed and tested under LR's Special Survey and in accordance with LR's Rules and Regulations, *see* Pt 3, Ch 8.

DRILL This notation will be assigned to units which have specialised structures and an installed drilling plant facility which has been constructed, installed and tested under LR's Special Survey and in accordance with LR's Rules and Regulations, *see* Pt 3, Ch 7.

DROPS This notation will be assigned to units which have preventive measures to protect personnel from the hazards of dropped objects in accordance with Pt 3, Ch 7,1.

PRS This notation will be assigned to units which have a product riser system which has been constructed, installed and tested under LR's Special Survey, in accordance with LR's Rules, *see* Pt 3, Ch 12.

OIWS This notation for In-Water Survey may be assigned to a unit where the applicable requirements of LR's Rules and Regulations are complied with, *see* Pt 1, Ch 3,4.3, Pt 3, Ch 1,2.1.3 and Pt 8, Ch 1,1.3.

2.4.14 The application of the **OIWS** notation to existing units will be subject to special consideration by the Classification Committee.

2.4.15 **LI**. This notation will be assigned to surface type units where an approved loading instrument has been installed as a classification requirement.

2.4.16 Details of unit types and additional special features class notations for which special Rules apply are incorporated in Part 3, *see also* 2.7.

2.4.17 **ShipRight notations**. The following optional special features notations are associated with LR's ShipRight Procedures and may be assigned in conjunction with the **ShipRight** notation to surface type units as considered appropriate by the Classification Committee, on application from Owners. The requirements pertaining to the notations and the ShipRight Procedures are given in Pt 3, Ch 16 of the Rules for Ships.

ShipRight SDA This notation (Structural Design Assessment) will be assigned with direct calculations in accordance with the ShipRight procedures which have been applied.

ShipRight FDA This notation (Fatigue Design Assessment) will be assigned when an appraisal has been made of the fatigue performance of the structure in accordance with the ShipRight Procedures and LR's *Structural Detail Design Guide*.

ShipRight FDA plus This notation (Fatigue Design Assessment plus) will be assigned when the appraisal has been made for a higher level of fatigue performance than that made for the assignment of **ShipRight FDA**.

ShipRight CM This notation (Construction Monitoring), which complements the **SDA** and **FDA** notations, will be assigned when the controls in construction tolerances detailed in the ShipRight procedures have been applied and verified.

2.4.18 When **ShipRight SDA**, **ShipRight FDA** and **ShipRight FDA plus** notations are assigned, the precise technical conditions of the appraisal will be made available to the Owners.

2.4.19 Where LR's ShipRight SDA procedure has been applied individually or where ShipRight SDA, ShipRight FDA, ShipRight FDA plus and ShipRight CM procedures have all been applied, whether on a voluntary or a mandatory basis, these particular class notations will appear on the *ClassDirect Live* website.

2.4.20 Special consideration will be given to assignment of additional notations given in Pt 1, Ch 2 of the Rules for Ships at the request of the Owner. The assignment of such notations will be conditional on compliance with all applicable requirements relevant to the unit type and service.

2.5 Class notations (machinery)

2.5.1 The following class notations are associated with machinery construction and arrangements, and may be assigned as considered appropriate by the Classification Committee:

✠OMC This notation will be assigned to non-propelled units when the essential auxiliary machinery has been constructed, installed and tested under LR's Special Survey and in accordance with LR Rules.

[✠]OMC This notation will be assigned to non-propelled units when:

- the pressure vessels and electrical equipment for essential systems have been constructed, installed and tested under LR's Special Survey and are in accordance with LR's Rules.
- other items of machinery and electrical power generation and other auxiliary machinery for essential services are in compliance with LR's Rules and supplied with the manufacturer's certificate.
- the system arrangement of essential auxiliary machinery is appraised and found to be acceptable to LR.

OMC This notation (without ✠) will be assigned to existing non-propelled units that will be accepted or transferred into LR class when:

- the essential auxiliary machinery has neither been constructed nor installed under LR's Special Survey.
- the existing machinery installation and arrangement have been tested and found to be acceptable to LR.

✠LMC This notation will be assigned when the propelling and essential auxiliary machinery has been constructed, installed and tested under LR's Special Survey and in accordance with LR Rules.

[✠]LMC This notation will be assigned to self-propelled units when:

- the propelling arrangements for propellers, propulsion shafting and multiple input/output gearboxes, steering systems, pressure vessels and electrical equipment for essential systems have been constructed, installed and tested under LR's Special Survey and are in accordance with LR's Rules.
- other items of machinery and gearing arrangements for propulsion and electrical power generation and other auxiliary machinery for essential services are in compliance with LR Rules and supplied with the manufacturer's certificate.
- the system arrangements of propelling and essential auxiliary machinery are appraised and found to be acceptable to LR.

LMC This notation (without ✠) will be assigned to existing self-propelled units that will be accepted or transferred into LR class when:

- the propelling and essential auxiliary machinery has neither been constructed nor installed under LR's Special Survey.
- the existing machinery installation and arrangement have been tested and found to be acceptable to LR.

IGS This notation will be assigned, when a unit having facilities for the storage of crude oil in bulk is fitted with an approved system for producing gas for inerting the crude oil storage tanks.

2.5.2 The following class notations are associated with the machinery control and automation, and may be assigned as considered appropriate by the Classification Committee:

UMS This notation may be assigned when the arrangements are such that the unit can be operated with the machinery spaces unattended. It denotes that the control engineering equipment has been arranged, installed and tested in accordance with LR's Rules, or that it is equivalent thereto.

CCS This notation may be assigned when the arrangements are such that the machinery may be operated with continuous supervision from a centralised control station. It denotes that the control engineering equipment has been arranged, installed and tested in accordance with LR's Rules, or is equivalent thereto.

ICC This notation may be assigned when the arrangements are such that the control and supervision of the unit's operational functions are computer based. It denotes that the control engineering equipment has been arranged, installed and tested in accordance with LR's Rules, or is equivalent thereto.

IP This notation may be assigned to a unit classed with LR when the arrangements of the machinery are such that the propulsion equipment and all the essential auxiliary machinery is integrated with the power unit for operation under all normal sea-going and manoeuvring conditions. The system is to be bridge controlled and the propulsion equipment is to incorporate an emergency means of propulsion in the event of failure in the prime mover. It also denotes that the machinery and control equipment has been arranged, installed and tested in accordance with LR's Rules.

2.5.3 The following special features class notations are associated with dynamic positioning arrangements and may be assigned as considered appropriate by the Classification Committee, *see* Pt 3, Ch 9:

DP(CM) This notation may be assigned when a unit is fitted with centralised remote manual controls for position keeping and with position reference system(s) and environmental sensor(s). It denotes that the machinery and control engineering equipment has been arranged, installed and tested in accordance with LR's Rules or is equivalent thereto.

DP(AM) This notation may be assigned when a unit is fitted with automatic main and manual standby controls for position keeping and with position reference system(s) and environmental sensor(s). It denotes that the machinery and control engineering equipment has been arranged, installed and tested in accordance with LR's Rules or that it is equivalent thereto.

DP(AA) This notation may be assigned when a unit is fitted with automatic main and automatic standby controls for position keeping and with position reference system(s) and environmental sensor(s). It denotes that the machinery and control engineering equipment has been arranged, installed and tested in accordance with LR's Rules, or that it is equivalent thereto.

DP(AAA) This notation may be assigned when a unit is fitted with automatic main and automatic standby controls for position keeping, together with an additional/emergency automatic control unit located in a separate compartment and with position reference systems and environmental sensors. It denotes that the machinery and control engineering equipment has been arranged, installed and tested in accordance with LR's Rules, or that it is equivalent thereto.

2.5.4 The dynamic positioning notations in 2.5.3 can be supplemented with a Performance Capability Rating notation (**PCR**). This rating indicates the calculated percentage of time that a unit is capable of holding heading and position under a standard set of environmental conditions (North Sea), *see* Pt 3, Ch 9.

2.5.5 Machinery class notations will not be assigned to units the hull/structure of which is not classed or intended to be classed with LR.

2.5.6 The notations **✠LMC**, **[✠]LMC** and **LMC** (without ✠) will not, in general, be assigned to non-self-propelled vessels.

2.5.7 Special consideration will be given to assignment of the additional notations given in Pt 1, Ch 2 of the Rules for Ships, at the request of the Owner. The assignment of such notations will be conditional on compliance with all applicable requirements relevant to the unit type and service.

2.6 Class notations (environmental protection)

2.6.1 The following class notations are associated with the design and operation of a unit and may be assigned as considered appropriate by the Classification Committee, on application from the Owners, *see* Pt 7, Ch 11 of the Rules for Ships:

ECO This notation will be assigned when a unit is designed and operated in accordance with the relevant requirements of the Rules for Ships.

ECO (TOC) This notation will be assigned when the environmental protection arrangements are in accordance with the requirements of another recognised classification society and are essentially equivalent to Rule requirements and the unit is operated in accordance with the relevant requirements of the Rules for Ships.

2.6.2 The class notations defined in 2.6.1 will be suspended on change of Owner or Manager until LR can confirm by audit that the necessary operational procedures required by the Rules for Ships are established.

2.7 Descriptive notes

2.7.1 In addition to any class notations, appropriate descriptive qualification notes may be entered on the *ClassDirect Live* website indicating the type of unit in greater detail than is contained in the class notation, and/or providing additional information about the design and construction, e.g., semi-submersible. A descriptive qualification is not a LR classification notation and is provided solely for information.

2.7.2 When an Owner requests LR to carry out Verification of a Classed unit in accordance with the Regulations of a National Administration, a descriptive note will be added on the *ClassDirect Live* website to indicate the applicable National Administration, e.g., Norwegian Verification (**N**), United Kingdom Verification (**UK**). *See* Pt 1, Ch 4.

2.7.3 Where an approved loading instrument is provided as an Owner's requirement, a descriptive note **LI** may be entered on the *ClassDirect Live* website.

2.7.4 Where LR's ShipRight procedures for the following have been applied on a voluntary basis to surface type units, a descriptive note will, at the Owner's request, be entered on the *ClassDirect Live* website, *see also ShipRight Procedures Overview* and Pt 1, Ch 2 of the Rules for Ships:

ES	Enhanced Scantlings
SEA (HSS-n)	Ship Event Analysis (Hull Surveillance Systems)
SERS	Ship Emergency Response Service
SCM	Screwshaft Condition Monitoring
MCM	Machinery Condition Monitoring
MCBM	Machinery Condition Based Maintenance
MPMS	Machinery Planned Maintenance Scheme
RCM	Reliability Centred Maintenance
BWMP	Ballast Water Management Plan.

2.7.5 Where evidence exists that supporting calculations have been performed in accordance with hull structural finite element and fatigue analysis procedures of a recognised Classification Society, then, on application from Owners, the descriptive note **ShipRight (E)** may be entered on the *ClassDirect Live* website.

■ *Section 3*
Surveys – General

3.1 Statutory surveys

3.1.1 The Classification Committee will act, when authorised on behalf of National Administrations, in respect of national and international statutory safety and other requirements for offshore units.

3.1.2 The Classification Committee will also act, when authorised, in respect of national safety, coastal state regulations and other requirements relating to offshore units used for the exploration and exploitation of hydrocarbons.

3.2 New construction surveys

3.2.1 When it is intended to build a unit for classification with LR, constructional plans and all necessary particulars relevant to the hull/structure, equipment and machinery, as detailed in the Rules, are to be submitted for the approval of LR before the work is commenced. Any subsequent modifications or additions to the scantlings, arrangements or equipment shown on the approved plans are also to be submitted for approval.

3.2.2 Where the proposed construction of any part of the hull/structure or machinery is of novel design, or involves the use of unusual material, or where experience, in the opinion of LR, has not sufficiently justified the principle or mode of application involved, special tests or examinations before and during service may be required. In such cases a suitable notation may be assigned.

3.2.3 The materials used in the construction of the hull/structure and machinery intended for classification are to be of good quality and free from defects and are to be tested in accordance with the requirements of the Rules for Materials. The steel is to be manufactured by an approved process at an approved works. Alternatively, tests will be required to demonstrate the suitability of the steel.

3.2.4 Materials used in the construction of drilling and process plant are to comply with 3.2.3 and with the requirements of Part 3.

3.2.5 New units intended for classification are to be built under LR's Special Survey. From the commencement of work until the completion of the unit, the Surveyors are to be satisfied that the materials, workmanship and arrangements are satisfactory and in accordance with the Rules. Any items found not to be in accordance with the Rules or the approved plans, or any material, workmanship or arrangements found to be unsatisfactory, are to be rectified.

3.2.6 For compliance with 3.2.5, LR is prepared to consider methods of survey and inspection for hull construction which formally include procedures involving the shipyard management, organisation and quality systems. The minimum requirements for the approval of any such proposed Quality Assurance methods are laid down in Pt 4, Ch 11.

3.2.7 Copies of approved plans (showing the unit as built), essential certificates and records, the Operations Manual and loading and other instruction manuals are to be readily available for use when required by the attending Surveyors, and may be required to be kept on board.

3.2.8 When the machinery and drilling/process plant of a unit are constructed under LR's Special Survey, this survey is to relate to the period from the commencement of the work until the final test under working conditions. Any items found not to be in accordance with the Rules or the approved plans, or any material, workmanship or arrangements found to be unsatisfactory, are to be rectified.

3.2.9 When remote and/or automatic control equipment, alarms and safeguards are fitted to the machinery and drilling/process plant, the equipment is to be arranged, installed and tested in accordance with LR's Rules and Regulations.

3.2.10 The date of completion of the Special Survey during construction of units built under LR's inspection will normally be taken as the date of build to be entered on the *ClassDirect Live* website. If the period between launching and completion or commissioning is, for any reason, unduly prolonged, the dates of launching and completion or commissioning may be separately indicated on the *ClassDirect Live* website.

3.2.11 When a unit, upon completion, is not immediately commissioned but is laid up for a period, the Classification Committee, upon application by the Owner prior to the unit being commissioned, will direct an examination to be made on site or in dry dock by the Surveyors. If, as a result of such survey, the structure, equipment and machinery are reported in all respects in accordance with applicable Rule requirements, the subsequent Special Survey and Complete Survey of the machinery will date from the time of such examination.

3.3 Existing installations

3.3.1 **Classification of units not built under survey**. The requirements of the Classification Committee for the classification of units which have not been built under LR's Survey are indicated in Ch 3,19. Special consideration will be given to units transferring class to LR from another recognised Classification Society.

3.3.2 **Reclassification**. When reclassification or class reinstatement is desired for a unit for which the class previously assigned by LR has been withdrawn or suspended, the Classification Committee will direct that a survey appropriate to the age of the unit and the circumstances of the case be carried out by the Surveyors. If, at such survey, the unit is found or placed in a condition in accordance with the requirements of the Rules and Regulations, the Classification Committee will be prepared to consider reinstatement of the original class or the assignment of such other class as may be deemed necessary.

3.3.3 The Classification Committee reserves the right to decline an application for classification or reclassification where the prior history of condition of the unit indicates this to be appropriate.

3.3.4 **Unscheduled surveys**. Where the Classification Committee has concern about the condition of the unit and/or the equipment, an unscheduled survey may be required at any time to determine the actual condition.

3.4 Damages, repairs and alterations

3.4.1 All repairs to hull/structure, equipment, machinery and drilling/process plant which may be required in order that a unit may retain its class, *see* 1.1.7, are to be carried out to the satisfaction of the Surveyors. Alternatively, the Classification Committee may agree, in exceptional cases, that quality control can be enforced by the Owner or repairer, on site, in which case the repairs are to be surveyed by the Surveyors at the earliest opportunity thereafter.

3.4.2 When, at any survey, the Surveyors consider repairs to be immediately necessary, either as a result of damage, or wear and tear, they are to communicate their recommendations at once to the Owner, or his representative. When such recommendations are not complied with, immediate notification is to be given to the Classification Committee by the Surveyors.

3.4.3 When, at any survey, it is found that any damage, defect or breakdown, *see* 1.1.7, is of such a nature that it does not require immediate permanent repair, but is sufficiently serious to require rectification by a prescribed date in order to maintain class, a suitable condition of class is to be imposed by the Surveyors and recommended to the Classification Committee for consideration.

3.4.4 If a unit which is classed with LR is damaged to such an extent as to necessitate towage outside port limits whilst in a damaged condition to a suitable repair facility, it shall be the Owner's responsibility to notify LR at the first practicable opportunity.

3.4.5 Plans and particulars of any proposed alterations to the approved scantlings and arrangements of hull/structure, equipment, machinery or drilling/process plant are to be submitted for approval, and such alterations are to be carried out to the satisfaction of the Surveyors.

3.5 Existing installations – Periodical Surveys

3.5.1 Annual Surveys are to be held on all units within three months, before or after each anniversary of the completion, commissioning or Special Survey, in accordance with the requirements given in Chapter 3. The date of the last Annual Survey will be recorded on the *ClassDirect Live* website.

3.5.2 Intermediate Surveys are to be held on all units instead of the second or third Annual Survey after completion, commissioning or Special Survey, in accordance with the requirements given in Ch 3,3. The Intermediate Survey may be commenced at the second Annual Survey and progressed with completion at the third Annual Survey. The date of the last Intermediate Survey will be recorded on the *ClassDirect Live* website. The concurrent crediting of items towards both Intermediate Survey and Special Survey is not permitted.

3.5.3 The Owner should notify LR whenever a unit can be examined in dry dock or on a slipway. A minimum of two Docking Surveys are to be held in each five-year Special Survey period and the maximum interval between successive Docking Surveys is not to exceed three years. One of the two Docking Surveys required in each five-year period is to coincide with the Special Survey. The Classification Committee will accept In-Water Surveys in lieu of Docking Surveys on units assigned an **OIWS** (In-Water Survey) notation, *see* Ch 3,4.3.

3.5.4 One of the two Docking Surveys or In-Water Surveys in lieu of Docking Surveys required in each five-year period is to coincide with the Special Survey, *see* 3.5.3. Consideration may be given in exceptional circumstances to an extension of this interval not exceeding three months beyond the due date. In this context 'exceptional circumstances' means unavailability of dry-docking facilities, repair facilities, essential materials, equipment or spare parts or delays incurred by action taken to avoid severe weather conditions.

3.5.5 The date of the last examination in dry dock or In-Water Survey will be recorded on the *ClassDirect Live* website.

3.5.6 Attention is to be given to all relevant statutory requirements of the National Authority in the country in which the unit is registered and/or is to operate.

3.5.7 When LR is to carry out verification on behalf of a National Authority, classification surveys required by the Rules, will, where practicable, be combined, and aligned, with the surveys required by the National Authority.

3.5.8 All units classed with LR are also to be subjected to Special Surveys in accordance with the requirements given in Ch 3,5. These surveys become due at five-yearly intervals, the first one five years from the date of build or date of Special Survey for Classification as recorded on the *ClassDirect Live* website, and thereafter five years from the date recorded for the previous Special Surveys. *See also* 3.2.10. Consideration can be given at the discretion of the Classification Committee to any exceptional circumstances justifying an extension of the hull classification to a maximum of three months beyond the fifth year. If an extension is agreed, the next period of hull classification will start from the date of the Special Survey before the extension was granted. A definition of 'exceptional circumstances' is given in 3.5.4.

3.5.9 Special surveys may be commenced at the fourth Annual Survey after completion, commissioning, or previous Special Survey, and be progressed during the succeeding year with a view to completion by the due date of the Special Survey. As part of the preparation for the Special Survey, the thickness determination, where applicable, may be dealt with in connection with the fourth Annual Survey.

3.5.10 Special Surveys which are commenced prior to their due date are not to extend over a period greater than 15 months, if such work is to be credited towards the Special Survey. Where the Special Survey is completed more than three months before the due date, the new record of Special Survey will be the final date of survey. In all other cases, the date recorded will be the fifth anniversary.

3.5.11 At the request of an Owner, it may be agreed that the Special Survey of the hull/structure be carried out on the Continuous Survey basis, where all compartments of the hull are to be opened for survey and testing, in rotation, with an interval of five years between consecutive examinations of each part. In general, approximately one fifth of the Special Survey is to be completed each year and all the requirements of the particular Special Survey of the hull/structure must be completed by the end of the five-year cycle. If the examination during Continuous Survey reveals any defects, further parts are to be opened up and examined as considered necessary by the Surveyor. For examination of items listed in Ch 3,2.2.10, 2.2.11, 2.6 and Ch 3,3.2.3, 3.2.4, 3.2.6, 3.2.8, 3.2.9 and 3.2.11, the intervals for inspection will require to be specially agreed. Units which have satisfactorily completed the cycle will have the date of completion entered on the *ClassDirect Live* website, which will not be later than five years from the last assigned date of complete Survey of the hull/structure. The agreement for surveys to be carried out on Continuous Survey basis may be withdrawn at the discretion of the Classification Committee.

3.5.12 The Owner is to prepare a planned survey programme for the inspection of the hull/structure after each Special Survey, before the next Annual Survey is due. The survey programme is to cover the requirements for Annual Surveys, Intermediate Surveys, Special Periodical Surveys, Special Continuous Surveys, Docking Surveys and In-Water Surveys in lieu of Docking Surveys and is to be submitted to LR for review. A copy is to be kept on board and made available to the Surveyor. The survey programme should include plans, etc., for identifying the areas to be surveyed, the extent of hull cleaning, locations for non-destructive examination (including NDE methods), nomenclature, and methods for the recording of any damage or deterioration found. The planned survey programme, as agreed by LR, will be subject to revision if it is found to be necessary at subsequent surveys, or when required by the Surveyor. *See* Ch 3,1.6.

3.5.13 The requirements for survey and the schedule of surveyable items may be amended when any variation in service duties, usage or change in type notation is proposed, by agreement between the Owner and the Classification Committee.

3.5.14 Machinery is to be subjected to the surveys detailed in Ch 3,6 to Ch 3,12.

3.5.15 Drilling/process plant, safety and communication systems and hazardous areas are to be subjected to the surveys detailed in Ch 3,13, 14 and 16.

3.5.16 Complete Surveys of machinery and drilling/process plant become due at five-yearly intervals, the first one from the date of build or date of first classification as recorded on the *ClassDirect Live* website and thereafter five years from the date recorded in the Survey records for the previous complete survey. Consideration can be given at the discretion of the Classification Committee to any exceptional circumstances justifying an extension of machinery class to a maximum of three months beyond the fifth year. If an extension is agreed to, the next period of machinery class will start from the due date of Complete Survey of machinery before the extension was granted. Surveys which are commenced prior to their due date are not to extend over a period greater than 15 months, except with the prior approval of the Classification Committee. On satisfactory completion of a survey, an appropriate entry will be made in the Survey Records. Where the survey is completed more than three months before the due date, the new date recorded will be the final date of survey. In all other cases, the date recorded will be the fifth anniversary.

3.5.17 Upon application by an Owner, the Classification Committee may agree to the extension of the survey requirements for main engines which, by the nature of the unit's normal service, do not attain the number of running hours recommended by the engines' manufacturer for major overhauls within the survey periods given in 3.5.16.

3.5.18 If it is found desirable that any part of the machinery should be examined again before the due date of the next survey, a certificate for a limited period will be granted in accordance with the nature of the case.

3.5.19 When, at the request of an Owner, it has been agreed by the Classification Committee that the Complete Survey of the machinery and/or drilling/process plant may be carried out on the Continuous Survey basis, the various items of machinery and plant are to be opened for survey in rotation, so far as is practicable, to ensure that the interval between consecutive examinations of each item will not exceed five years. In general, approximately one fifth of the machinery and plant is to be examined each year. A record indicating the date of satisfactory completion of the Continuous Survey cycle will be made in the Survey Records.

3.5.20 If any examination during Continuous Survey reveals defects, further parts are to be opened up and examined as considered necessary by the Surveyor, and the defects are to be made good to the Surveyor's satisfaction.

3.5.21 Upon application by an Owner, the Classification Committee may agree to an arrangement whereby, subject to certain conditions, some items of machinery may be examined by the Chief Engineer of the unit followed by a limited confirmatory survey carried out later by an Exclusive Surveyor. Particulars of this arrangement may be obtained from LR. Where an approved planned maintenance scheme is in operation, the confirmatory surveys may be held at annual intervals, at which time the records will be checked and the operation of the scheme verified. Particulars of this arrangement may be obtained from LR.

3.5.22 Where condition monitoring equipment is fitted, the Classification Committee, upon application by the Owner, will be prepared to amend applicable Periodical Survey requirements where details of the equipment are submitted and found satisfactory. Where machinery installations are accepted for this method of survey, it will be a requirement that an Annual Survey be held, at which time monitored records will be analysed and the machinery examined under working conditions. An acceptable lubricating oil trend analysis programme may be required as part of the condition monitoring procedures.

3.5.23 The survey of boilers and other pressure vessels and the examination of steam pipes and Screwshaft Surveys are to be carried out as stated in Ch 3,10 to Ch 3,12.

3.5.24 The survey of pressure vessels for process and drilling plant is to be carried out as stated in Ch 3,17.

3.5.25 Where any inert gas system is fitted for the protection of storage tanks on board a unit intended for the storage of crude oil in bulk, the system is to be surveyed annually in accordance with the requirements of Ch 3,2.6. In addition, on units to which an **IGS** notation has been assigned, a Special Survey of the inert gas plant is to be carried out at intervals not exceeding five years, in accordance with the requirements of Ch 3,18.

3.5.26 Where the unit is fitted with a dynamic positioning system, the system is to be examined and tested annually, in accordance with the requirements of Ch 3,2.3.15. In addition, a Special Survey is to be carried out at intervals not exceeding five years, in accordance with Ch 3,6.2.10.

3.5.27 Where the Committee has agreed to an Owner's request to assign the notation 'laid-up', the unit may be retained in class provided a satisfactory general examination of the hull and machinery is carried out at the Annual Survey due date and an Underwater Examination (UWE) is carried out at the Special Survey due date. The general examination may be carried out within three months before or after the Annual Survey due date.

3.6 Certificates

3.6.1 When, on completion of the survey of new or existing units which have been submitted for classification, the required reports have been received from the Surveyors and classification has been agreed by the Classification Executive, a certificate of Classification may be issued by an authorised Surveyor. After approval by the Classification Committee, a certificate of First Entry of Classification, signed by LR's Chairman or the Chairman of the Classification Committee, will be issued to Builders or Owners.

3.6.2 A Certificate of Class valid for five years subject to endorsement for Annual and Intermediate Surveys will also be issued to the Owners.

3.6.3 LR Surveyors are permitted to issue provisional (interim) certificates to enable an offshore unit classed with LR to proceed on its voyage or to continue in service, provided that, in their opinion, the unit is in a fit and efficient condition. Such certificates will embody the Surveyor's recommendations for continuance of class, but in all cases are subject to confirmation by the Classification Committee.

3.6.4 The full class notation and abbreviated descriptive notes shall be stated on the Certificate of Class and the provisional (interim) certificates.

3.6.5 Under no circumstances is the extension of validity of a class certificate to be granted beyond the due date of a Periodical Survey without the essential inspection (including NDE) having been completed for all prescribed parts of the primary structure.

3.7 Notice of surveys

3.7.1 It is the responsibility of the Owner to ensure that all surveys necessary for the maintenance of class are carried out at the proper time and in accordance with the instructions of the Classification Committee. Information is available to Owners on the *ClassDirect Live* website.

3.7.2 LR will make every effort to give timely notice to an Owner about forthcoming surveys. The omission of such notice, however, does not absolve the Owner from his responsibility to comply with LR's survey requirements for maintenance of class, all of which are available to Owners on the *ClassDirect Live* website.

3.8 Temporary suspension of class

3.8.1 When an Owner intends to move a classed unit to a new operating area and, due to the unit's significant design criteria, it is not suitable for exposed sea passages outside its normal operating area, the certificate of class will automatically be suspended during sea voyages. Class will be reinstated provided that the environmental criteria for the new area do not exceed the design criteria, and that an inspection by LR Surveyors when the unit arrives in the new area establishes that the hull/structure has suffered no damage in transit and remains in an efficient condition.

3.8.2 When it is contemplated to tow a unit to an area which is outside the normal operating area of the unit, the towing arrangements are to be approved and certified by a competent authority for the particular voyage.

3.8.3 Although it is not generally a condition of class that the assessment of a unit as being fit for a particular sea passage should be undertaken by LR, when requested, LR is prepared to advise on the measures to be adopted for such a voyage, to supervise their execution and to issue the appropriate certificates.

3.8.4 All units will remain in class during location moves (i.e., moves within the same operational area) provided that:
(a) approved procedures stated in the unit's Operations Manual are adhered to;
(b) the towing arrangements and equipment on non-propelled units are to comply with Pt 4, Ch 9,2; and
(b) reports of any inspections of critical areas carried out during such moves are retained for review, where appropriate, by the Surveyors.

3.9 Withdrawal/suspension of class

3.9.1 When the class of a unit, for which the Regulations with regard to surveys on hull/structure, equipment and machinery have been complied with, is withdrawn by the Classification Committee as a result of a request from the Owner, the notation 'Class withdrawn at Owner's request' (with date) will be assigned.

3.9.2 When the Regulations with regard to survey on the hull/structure, equipment, machinery or the drilling/process plant have not been complied with and the unit thereby is not entitled to retain class, the class will be suspended or withdrawn, at the discretion of the Classification Committee, and a corresponding notation will be assigned.

3.9.3 Class will be automatically suspended and the Certificate of Class will become invalid if the Annual or Intermediate Survey is not completed within three months of the due date of the survey.

3.9.4 Class will be automatically suspended from the expiry date of the Certificate of Class in the event that the Special Survey has not been completed by the due date and an extension has not been agreed, *see* 3.5.8, or is not under attendance by the Surveyors with a view to completion prior to resuming operations.

3.9.5 When, in accordance with 3.4.3 of the Regulations, a condition of class is imposed, this will be assigned a due date for completion and the unit's class may be suspended if the condition of class is not dealt with, or postponed by agreement, by the due date.

3.9.6 If it is found, from the reported condition of the hull or equipment or machinery or the drilling/process plant of a unit that an Owner has failed to comply with 1.1.7, 1.1.12, 1.1.13, 1.1.14, 3.4.1, 3.4.4 or 3.4.5, the class will be liable to be suspended or withdrawn, at the discretion of the Classification Committee, and a corresponding notation assigned. If it is considered that an Owner's failure to comply with these requirements is sufficiently serious, the suspension or withdrawal of class may be extended to include other units controlled by the same Owner, at the discretion of the Classification Committee.

3.9.7 If the Classification Committee is satisfied that a unit has been operated in a manner contrary to that agreed at the time of classification, or is being operated in environmental conditions which are more onerous than, or in areas other than, those agreed by the Classification Committee, the class will be withdrawn or suspended in relation to those operations.

3.9.8 If the Classification Committee is satisfied that a unit proceeded to sea with less freeboard than that approved by the Classification Committee, or that the freeboard marks are placed higher on the sides of the unit than the position assigned or approved by the Classification Committee, or, in cases where units do not have freeboards assigned, the draught is greater than that approved by the Classification Committee, the class of the unit will be withdrawn or suspended in relation to the above voyages.

3.9.9 In all instances of class withdrawal or suspension, the assigned notation, with date of application, will be published by members of the LR Group. In cases where class has been suspended by the Classification Committee and it becomes apparent that the Owners are no longer interested in retaining LR's Class, it will be withdrawn.

3.9.10 For reclassification and reinstatement of class, *see* 3.3.2.

3.10 Appeal against Surveyor's recommendations

3.10.1 If the recommendations of the Surveyors are considered in any case to be unnecessary or unreasonable, appeal may be made to the Classification Committee, who may direct a Special Examination to be held.

3.11 Ownership details

3.11.1 It is the responsibility of the Owner to inform a member of the LR Group in writing of any change to its contact details and, in the event of a unit sale, to supply details of the new Owners. If the new Owner of a unit cannot be properly identified nor contact details established, then the class of that unit will be specially considered by the Classification Committee. It is the responsibility of the new Owner to inform a member of the LR Group in writing of their contact details and that they are now responsible for the unit. If they fail to do so, the class of that unit will be specially considered by the Classification Committee.

■ *Section 4*
IACS and EMSA audits and assessments

4.1 Audit of surveys

4.1.1 The surveys required by the Regulations may be subject to audit or assessment in accordance with the requirements of the International Association of Classification Societies and European Maritime Safety Agency requirements.

■ *Section 1* General

1.1 Frequency of surveys

1.1.1 The requirements of this Chapter are applicable to the Periodical Surveys set out in Ch 2,3.5. Except as amended at the discretion of the Classification Committee, the periods between such surveys are as follows:

(a) Annual Surveys, as required by Ch 2,3.5.1.
(b) Intermediate Surveys as required by Ch 2,3.5.2.
(c) Docking Surveys and In-water Surveys as required by Ch 2,3.5.3 and 3.5.4.
(d) Special Surveys at five-yearly intervals, *see* Ch 2,3.5.8, for alternative arrangements, *see also* Ch 2,3.5.10, 3.5.11 and 3.5.12.
(e) Complete Surveys of machinery at five-yearly intervals, *see* Ch 2,3.5.17.

1.1.2 When it has been agreed that the complete survey of the hull and machinery may be carried out on the Continuous Survey basis, all compartments of the hull and all items of machinery are to be opened for survey in rotation to ensure that the interval between consecutive examinations of each part will not exceed five years, *see* Ch 2,3.5.11 and 3.5.19. The requirements of 1.1.1(a) to (c) are also to be complied with.

1.1.3 **Surface type units:** for units with crude oil bulk storage tanks, the additional requirements of Pt 1, Ch 3, Sections 2, 3, 4, 5 and 7 of the Rules for Ships are to be complied with, as applicable.

1.1.4 For the frequency of surveys of boilers and other pressure vessels, steam pipes, screwshafts, tube shafts, propellers and thrusters, *see* Sections 10 to 12, *see also* 1.1.5.

1.1.5 For the frequency of surveys of pressure vessels for process and drilling plant, *see* Section 17.

1.1.6 For the frequency of surveys of process/drilling plant, *see* Sections 13 and 14.

1.1.7 For the frequency of surveys of inert gas systems, *see* Section 18.

1.1.8 For the frequency of surveys of safety and communication systems and hazardous areas, *see* Section 16.

1.2 Surveys for damage or alterations

1.2.1 At any time when a unit is undergoing alterations or damage repairs, any exposed parts of the structure normally difficult to access are to be specially examined, e.g., if any part of the main or auxiliary machinery, including boilers, insulation or fittings, is removed for any reason, the steel structure in way is to be carefully examined by the Surveyor, or when cement in the bottom or covering on decks is removed, the plating in way is to be examined before the cement or covering is relaid.

1.3 Unscheduled surveys

1.3.1 In the event that LR has cause to believe that its Rules and Regulations are not being complied with, LR reserves the right to perform unscheduled surveys of the hull, machinery, or drilling/process plant and the applicable statutory requirements, whether or not the appropriate statutory certificate has been issued by LR.

1.3.2 In the event of significant damage or defect affecting any unit, LR reserves the right to perform unscheduled surveys of the hull structure or machinery of other similar units classed by LR and deemed to be vulnerable.

1.4 Surveys for the issue of Convention Certificates

1.4.1 Surveys are to be held by LR when so appointed, or by the Exclusive Surveyors to a National Administration or by an IACS Member, when so authorised by the National Authority, or, in the case of Cargo Ship Safety Radio Certificates or Safety Management Certificates, by any organisation authorised by the National Authority. In the case of dual classed units, Convention Certificates may be issued by the other Society with which the unit is classed, provided this is recognised in a formal Dual Class Agreement with LR and provided the other Society is also authorised by the National Authority.

1.5 Definitions

1.5.1 **Unit types** are defined in Ch 2,2 and Part 3.

1.5.2 **Critical areas** are locations vulnerable to substantial corrosion, buckling and/or fatigue cracking.

1.5.3 A **ballast tank** is a tank which is used solely for salt-water ballast. A space which is used for both the storage of liquids and salt-water ballast will be treated as a salt-water ballast tank when substantial corrosion has been found in that space.

1.5.4 **Spaces** are separate compartments such as tanks, pump-rooms, cofferdams and void spaces bounding cargo holds, decks and outer hull.

1.5.5 An **Overall Survey** is a survey intended to report on the overall condition of the hull structure and to determine the extent of additional Close-up Surveys as necessary.

1.5.6 A **Close-up Survey** is a survey where the details of structural components are within the close visual inspection range of the Surveyor, i.e., normally within reach of hand.

1.5.7 **Representative spaces** are those which are expected to reflect the condition of other spaces of similar type and service and with similar corrosion prevention systems. When selecting representative spaces, account should be taken of the service and repair history on board and identifiable Critical Structural Areas.

1.5.8 **Substantial corrosion** is wastage of individual plates and stiffeners in excess of 75 per cent of allowable margins, but within acceptable limits.

1.5.9 A **corrosion preventing system** is normally a full hard protective coating. This is usually to be an epoxy coating or equivalent. For other systems, with the exception of soft and semi-hard coatings, *see* Pt 1, Ch 3,1.5.16 of the Rules for Ships.

1.5.10 An **independent double bottom tank** is a double bottom tank which is separate from topside tanks, side tanks or deep tanks.

1.5.11 **NDE** is Non-Destructive Examination, consisting of visual examination and Non-Destructive Testing (NDT).

1.5.12 **Coating condition** is defined as follows:

GOOD Condition with only minor spot rusting.

FAIR Condition with local breakdown of coating at edges of stiffeners and weld connections and/or light rusting over 20 per cent or more of areas under consideration, but less than as defined for poor condition.

POOR Condition with general breakdown of coating over 20 per cent of areas and hard scale at 10 per cent or more of area under consideration.

1.5.13 A **prompt and thorough repair** is a permanent repair completed at the time of survey to the satisfaction of the Surveyor, thereby removing the need for the imposition of any associated condition of class or recommendation.

1.5.14 **Critical structural areas** are locations which have been identified from calculations to require monitoring or from the service history of the subject unit or from similar units, if applicable, to be sensitive to cracking, buckling or corrosion which would impair the structural integrity of the unit.

1.6 Planned survey programme

1.6.1 A planned survey programme is to be developed by the Owner and submitted to LR for approval in advance of the first survey, *see* Ch 2,3.5.12. The programme should include guidance for control and recording of all relevant aspects of the inspection and replacement philosophy. In particular, the programme is to include and address the following:

(a) the overall design configuration;
(b) field life potential;
(c) appropriate regulatory requirements;
(d) main hull structural arrangement plans;
(e) details of planning, identification and preparation procedures;
(f) areas to be surveyed and extent of hull cleaning;
(g) inspection and testing schedules for all relevant compartments, equipment and systems;
(h) inspection methods and procedures;
(j) extent, frequency and circumstances for application of NDE;
(k) locations for non-destructive testing;
(l) schedule for overall survey, close-up survey and thickness measurement;
(m) condition of coatings and corrosion prevention systems;
(n) methods for reporting and recording of damage or deterioration found and remedial measures;

(o) allowable wastage limits (corrosion margins and wear allowances) for each part of the structure and mooring system.

1.6.2 Particular attention is to be paid to critical areas and also to areas of suspected damage or deterioration and to repaired areas. Surveys are to take into account locations highlighted by service experience and the design assessment.

1.6.3 A planned survey programme for positional mooring systems is to be developed by the Owner and submitted to LR for approval, *see* 2.2.11.

1.6.4 A planned survey programme for installations assigned a **PPF** notation and/or a **DRILL** notation is to be developed by the Owner and submitted to LR for approval, *see* 2.5.5 and 2.7.1.

1.6.5 Planned surveys and procedures as agreed by LR will be subject to revision if found necessary at subsequent surveys or when required by the Surveyor.

1.6.6 A planned survey programme for installations with riser systems assigned a **PRS** notation is to be developed by the Owner and submitted to LR for approval, *see* Section 15.

1.7 Preparation for survey and means of access

1.7.1 In order to enable the attending Surveyor(s) to carry out the survey, provision for proper and safe access is to be agreed between the Owner and LR. Tanks and spaces are to be safe for access, gas free and properly ventilated. Prior to entering a tank, void or enclosed space, it is to be verified that the atmosphere in that space is free from hazardous gas and contains sufficient oxygen.

1.7.2 In preparation for survey, thickness measurements and to allow for a thorough examination, all spaces are to be cleaned, including removal from surfaces of all loose accumulated corrosion scale. Spaces are to be sufficiently clean and free from water, scale, dirt, oil residues, etc., to reveal corrosion, deformation, fractures, damages or other structural deterioration as well as the condition of the protective coating. However, those areas of structure whose renewal has already been decided by the Owner need only be cleaned and descaled to the extent necessary to determine the limits of renewed areas.

1.7.3 Sufficient illumination is to be provided to reveal corrosion, deformation, fractures, damages or other structural deterioration.

1.7.4 Means are to be provided to enable the Surveyor to examine the structure in a safe and practical way.

1.7.5 Survey at an offshore location or anchorage may be undertaken when the Surveyor is fully satisfied with the access, egress and communications arrangements provided and that the personnel on board are competent in the application and use of all relevant safety and communications equipment and procedures.

1.7.6 Where soft or semi-hard coatings have been applied, safe access is to be provided for the Surveyor to verify the effectiveness of the coating and to carry out an assessment of the conditions of internal structures which may include spot removal of the coating. When safe access cannot be provided, the soft or semi-hard coating is to be removed.

1.8 Thickness measurement at survey

1.8.1 This Section is applicable to the thickness measurement of the structure where required by Sections 2, 3, 4 and 5.

1.8.2 Prior to the commencement of the Intermediate Survey and Special Survey, a meeting is to be held between the attending Surveyor(s), the Owner's representative in attendance, the thickness measurement company representative and the Master of the unit or an appropriately qualified representative appointed by the Master or Owner, so as to ensure the safe and efficient conduct of the survey and thickness measurements to be carried out. *See also* 1.6.1.

1.8.3 Thickness measurements are normally to be taken by means of ultrasonic test equipment and are to be carried out by a firm approved in accordance with LR's *Approval for Thickness Measurement of Hull Structure*.

1.8.4 The Surveyor may require to measure the thickness of the material in any portion of the structure where signs of wastage are evident or wastage is normally found. Any parts of the structure which are found defective or excessively reduced in scantlings are to be made good by materials of the approved scantlings and quality. Attention is to be given to the structure in way of discontinuities. Surfaces are to be re-coated as necessary.

1.8.5 Thickness measurements are to be taken in the forward and aft areas of all plates. Where plates cross ballast/cargo tank boundaries, separate measurements for the area of plating in way of each type of tank are to be reported. In all cases, the measurements are to represent the average of multiple measurements taken on each plate and/or stiffener. Where measured plates are renewed, the thickness of adjacent plates in the same strake is to be reported.

1.8.6 Thickness measurement of units with storage tanks for liquefied gases or chemicals will be specially considered.

1.8.7 The extent and frequency of thickness measurement on structure with substantial corrosion will be specially considered. The survey will not be considered complete until all required thickness measurements have been carried out.

1.8.8 Thickness measurements are to be witnessed by the Surveyor to the extent necessary to control the process. This also applies to thickness measurements carried out while the unit is at an offshore location.

1.8.9 Thickness measurements may be carried out within the 12 months prior to the due date of the Special Survey.

1.8.10 Where it is required as part of the survey to carry out thickness measurements for the structural areas subject to Close-up Survey, these measurements are to be carried out simultaneously with the Close-up Survey.

1.8.11 The Surveyor may extend the scope of thickness measurement if deemed necessary.

1.8.12 Thickness determination by drilling structural members is not permitted.

1.8.13 In all cases, the extent of the thickness measurements is to be sufficient to represent the actual average condition.

1.8.14 A report is to be prepared by the approved firm carrying out the thickness measurements. The report is to give the location of measurement, the thickness measured as well as the corresponding original thickness. The report is to give the date when measurement was carried out, the type of measuring equipment, names of personnel and their qualifications and is to be signed by the Operator.

1.8.15 The thickness measurement report is to be verified and signed by the Surveyor and countersigned by an authorising Surveyor.

1.9 Repairs

1.9.1 Any damage in association with wastage over the allowable limit (including buckling, grooving, detachment or fracture), or extensive areas of wastage over the allowable limits, which affects or, in the opinion of the Surveyor, will affect the ship's structural, watertight or weathertight integrity, is to be promptly and thoroughly repaired. Areas to be considered include, (where fitted):

- side shell frames, their end attachments and adjacent shell plating;
- deck structure and deck plating;
- bottom structure and bottom plating;
- side structure and side plating;
- inner bottom structure and inner bottom plating;
- inner side structure and inner side plating;
- watertight or oiltight bulkheads;
- hatch covers and hatch coamings.

For locations where adequate repair facilities are not available, consideration may be given to allow the ship to proceed directly to a repair facility. This may require discharging the cargo and/or temporary repairs for the intended voyage.

1.9.2 Where it is proposed to defer repairs, a defect criticality assessment is to be submitted for approval, demonstrating the effectiveness of any mitigation measures (*inter alia* monitoring, loading restrictions) and continued suitability until repaired.

■ *Section 2*
Annual Surveys – Hull and machinery requirements

2.1 General

2.1.1 Annual Surveys are to be held concurrently with statutory annual or other relevant statutory surveys, wherever practicable.

2.1.2 At Annual Surveys, the Surveyor is to examine the unit and machinery, so far as necessary and practicable, in order to be satisfied as to their general condition.

2.1.3 For surface type units which are required by International Convention to comply with the International Safety Management Code (ISM Code), the Surveyor is to review the overall effectiveness of the Code on board the installation. This is to be undertaken regardless of the organisation issuing the Safety Management Certificate (SMC).

2.2 Structure and equipment

2.2.1 At each Annual Survey the exposed parts of the hull structure, deck, deck-houses, superstructures and structures attached to the deck, including supports to drilling/process plant, derrick substructures, crane pedestals and other supporting structures, accessible internal spaces and the applicable parts listed under unit types, as specified in 2.2.2 to 2.2.5, are to be generally examined and the Surveyor is to be satisfied as to their efficient condition.

2.2.2 **All unit types**. The Surveyor is to be satisfied regarding the efficient condition of:

- Hatchways, manholes and other openings in freeboard and superstructure decks or leading into buoyant spaces.
- Machinery casings and covers, companionways, and deck-houses protecting openings.
- Side scuttles and deadlights, and other openings in hull shell boundaries or in enclosed superstructures.
- Ventilators and air pipes together with flame screens, fiddley openings, skylights, flush deck scuttles and overboard discharges from enclosed spaces. In addition, the Surveyor is to examine externally all air pipe heads installed on exposed decks.
- Closing appliances for all the above, including check valves, hatch covers and doors, together with their respective securing devices, sills, coamings and supports.
- Watertight bulkheads, and end bulkheads of enclosed superstructures.
- Watertight doors and hatch covers in watertight boundaries, their indicators and alarms, to be examined and tested (locally and remotely), together with an examination of watertight boundary penetrations, so far as is practicable.
- Freeing ports together with bars, shutters and hinges.
- Windlasses and attachment of anchor racks and anchor cables.

- Protection of the crew, guard-rails, life-lines, gangways and deck-houses accommodating crew.
- The type, location and extent of corrosion control (i.e., coatings, cathodic protection systems, etc.), as well as its effectiveness, and repairs or renewals should be reported at each survey.

2.2.3 **Column-stabilised units**. At the first Annual Survey subsequent to build, units are subject to examination of major structural components including NDE of critical areas, *see also* 1.6 and Ch 2,3.5.12. The Annual Survey is to include a complete bracing Close-up Survey, consisting of a detailed dry examination of all bracings and their structural connections to columns, pontoons and decks. The following critical regions are to be examined by approved methods of NDE:

(a) Primary bracing shell plating, including butts and seams and welding in way of the toes of both internal and external brackets (i.e., axial gusset or diaphragm plates and stiffener ends).
(b) Primary bracing shell plating and welding in way of changes of section, connections to main structure (e.g., columns, lower hulls, pontoons, decks, etc.) and intersections with other braces or node fabrications.
(c) All penetrations and attachments to primary bracings including drain, vent and access holes, hydrophone mountings, together with edge reinforcements, attachments for cathodic protection (both sacrificial anodes and impressed current systems), and guard-rail mountings, eye plates or lugs, etc.
(d) Diaphragm, bulkhead or deck plating and welding inside columns, pontoons or upper hull connection areas, in way of ends of primary bracings, local shear gussets between adjacent tube ends, and gussets, brackets of stiffeners forming a continuity of axial members from inside bracings. Also, column or deck plating and welded connections to bracings in way of internal diaphragm inside bracing.
(e) Column connections to lower hulls, pontoons and upper hull structure, including internal supporting structure.
(f) The structure in way of tether connections on tension-leg units.

It is important that an agreed procedure be established for the schedule of extent of examination and the proportion of NDE required at subsequent surveys, *see also* Ch 2,3.5.13. Specific critical regions are to be examined by approved methods of NDE. Column structure and upper hull structure where accessible above the waterline are to be generally examined.

2.2.4 **Self-elevating units**. At the first Annual Survey subsequent to build, units are subject to examination of major structural components, including NDE of critical areas, *see also* 1.6 and Ch 2,3.5.12. The Surveyor is to be satisfied regarding the efficient condition of:

- Jack-house structures and attachments to upper hull or platform.
- Jacking or other elevating systems and leg guides, externally.
- Legs as accessible above the waterline.
- Plating and supporting structure in way of leg wells.
- Drilling derrick support structure.

It is important that an agreed procedure is established for the schedule of extent of examination and the proportion of NDE required at subsequent surveys, *see also* Ch 2,3.5.12. Specific critical regions to be examined by approved methods of NDE include the following:

(a) Leg guides and hull support structure.
(b) Leg well bulkheads below jacking tower or jack-house.
(c) Connections between jack-house structure and main deck and underdeck supporting structure.
(d) The jack-house roof above the jacking machinery (i.e., above the shock foundation) and in the vicinity of upper guide structure.
(e) General inspection of bracings, gussets, chord joints and racks of the legs. Inspection of tubular or similar type legs including pin holes.
(f) Leg connections to bottom mats or spud cans.
(g) Drilling derrick supporting structure.

2.2.5 **Surface type units**. The requirements of Pt 1, Ch 3,2 of the Rules for Ships are to be complied with, as applicable. The Surveyor is to be satisfied regarding the efficient condition of:

- The hull and deck structure around the drilling wells and moonpools and in the vicinity of any other structural changes in section, slots, steps, or openings in the deck or hull and the back-up structure in way of structural members or sponsons connecting the hull.

2.2.6 The Surveyor is to confirm that an approved Operations Manual and Construction Portfolio are available on board, *see* Pt 3, Ch 1,3.

2.2.7 Where applicable, the following are to be examined where accessible:

- The hull and deck structure around turret openings and turret areas.
- Turret bearings and seals.
- Mooring arms and yokes.
- Mooring arm pivots and bearings.
- Process plant support stools and deck structure in way.
- Swivel stack support structure.
- Swivel stack bearing and seals.
- Mooring hawser line and mooring arm attachments to the hull structure.
- Mooring hawser to buoy.

2.2.8 The Surveyor is to confirm that, where required, an approved loading instrument, together with its operating instructions, is available on board, *see* Ch 2,1.1.9 and 1.1.10. The operation of the loading instrument is to be verified in accordance with LR's certification procedure.

2.2.9 For disconnectable units with equipment in accordance with Pt 4, Ch 9, anchors, cables, windlasses and winches are to be examined so far as practicable.

2.2.10 For units fitted with positional mooring equipment in accordance with Pt 3, Ch 10, an initial inspection is to be carried out following the installation of the positional mooring system, to ensure that the system has been properly installed and has not suffered damage.

2.2.11 For units fitted with positional mooring equipment which have been assigned a special features notation in accordance with Pt 3, Ch 10, a rota of component parts of the mooring system is to be examined at each Annual Survey. A periodic inspection program is to be developed by the Owners/Operators and submitted to LR for approval. Annual Surveys should be capable of determining as far as practicable the general condition of the mooring system including cables, chains, fittings, fairleads, connections and equipment. The Surveyor is to be satisfied that all components and equipment remain in an acceptable condition.
Particular attention is to be given to the following:
- Cable or chain in contact with fairleads, etc.
- Cable or chain in way of winches and stoppers.
- Cable or chain in way of the splash zone.

2.2.12 The Surveyor is to be satisfied regarding the freeboard marks on the unit's side.

2.2.13 The Surveyor is to be satisfied at each Annual Survey that no material alterations have been made to the unit, its structural arrangements, mooring system, subdivision, superstructure, fittings, and closing appliances upon which the stability approval and load line assignment is based.

2.2.14 The requirements of 3.2.3, 3.2.4, 5.3.5 and 5.3.6 regarding the survey of water ballast spaces are also to be complied with, as applicable.

2.2.15 The Surveyor is to carry out an examination and thickness measurement of areas identified at the previous Special Survey or Intermediate Survey as having substantial corrosion, *see* Section 5.

2.2.16 The Survey requirements for sea bed-stabilised units will be specially considered, but the requirements for column-stabilised and self-elevating units are to be compilied with as applicable.

2.2.17 Survey requirements for units used for the storage of liquefied gas or chemicals will be specially considered.

2.3 Machinery

2.3.1 The main propulsion, essential auxiliary and emergency generators, including safety arrangements, controls and foundations, are to be generally examined. Surveyors are to confirm that Periodical Surveys of engines have been carried out as required by the Rules and that safety devices have been tested.

2.3.2 For units which are disconnectable in order to avoid hazards or extreme storm conditions, unless agreed otherwise with LR, the Surveyor is to examine and test in operation all main and auxiliary steering arrangements, including their associated equipment and control systems, and verify that log book entries have been made in accordance with statutory requirements, where applicable. For laid-up machinery, *see* Section 20.

2.3.3 The Surveyor is to inspect generally the machinery and boiler spaces, with particular attention being given to the propulsion system, auxiliary machinery, and any potential fire and explosion hazards. Emergency escape routes are to be checked to ensure that they are free from obstruction.

2.3.4 The means of communication between the navigating bridge and the machinery control positions are to be tested.

2.3.5 The bilge pumping systems and bilge wells, including operation of extended spindles and level alarms, where fitted, are to be examined so far as is practicable. Satisfactory operation of the bilge pumps is to be proven.

2.3.6 Piping systems containing oil fuel, lubricating oil or other flammable liquids are to be generally examined and operated, as far as practicable, with particular attention being paid to tightness, fire precaution arrangements, flexible hoses and sounding arrangements.

2.3.7 The Surveyor is to be satisfied regarding the condition of non-metallic joints in piping systems which penetrate the hull, where both the penetration and the non-metallic joint are below the deepest load waterline.

2.3.8 Boilers and other pressure vessels and their appurtenances, including safety devices, foundations, controls, relieving gear, high pressure and waste steam piping insulation and gauges, are to be generally examined. Surveyors are to confirm that Periodical Surveys of boilers and other pressure vessels have been carried out as required by the Rules and Regulations. Pressure vessels for process and drilling plant are to be examined in accordance with Section 17.

2.3.9 For boilers, the safety devices are to be tested and the safety valves are to be operated using the relieving devices. For exhaust gas heated economisers/boilers, the safety valves are to be tested at sea by the Chief Engineer and details recorded in the Log Book.

2.3.10 The operation and maintenance records, repair history and feed water chemistry records of boilers are to be examined.

2.3.11 Gas and crude oil burning systems are to be generally examined and safety devices tested. Surveyors are to confirm that Periodical Surveys have been carried out as required by Section 10.

2.3.12 The electrical equipment and cabling forming the main and emergency electrical installations are to be generally examined under operating conditions, so far as is practicable. The satisfactory operation of the main and emergency sources of power and electrical services essential for safety in an emergency is to be verified; where the sources of power are automatically controlled, they should be tested in the automatic mode.

2.3.13 Bonding straps for the control of static electricity and earthing arrangements are to be examined, where fitted.

2.3.14 For units having **UMS** or **CCS** notation, a General Examination of automation equipment is to be carried out. Satisfactory operation of safety devices and control systems is to be verified.

2.3.15 For units fitted with a dynamic positioning system and/or a thruster-assisted positional mooring system, the control system and associated machinery items are to be generally examined and tested under operating conditions to an approved Test Schedule.

2.3.16 For units fitted with automation equipment for main propulsion, essential auxiliary and emergency machinery, a general examination of the equipment and arrangements is to be carried out. Records of changes to the hardware and software used for controlling and monitoring systems for propelling and essential auxiliary machinery since the original issue (and their identification) are to be reviewed by the attending Surveyor. Satisfactory operation of the safety devices and controls systems is to be verified.

2.3.17 For units fitted with an electronically controlled engine for main propulsion, essential auxiliary or emergency power purposes, the following is to be carried out to the satisfaction of the Surveyor:

(a) Verification of evidence of satisfactory operation of the engine; where possible, this is to include a running test under load.
(b) Verification of satisfactory operation of the safety devices and control, alarm and monitoring systems.
(c) Verification that any changes to the software or control, alarm, monitoring and safety systems that affect the operation of the engine have been assessed by LR and are under configuration management control.

2.3.18 Dead unit starting arrangements for bringing machinery into operation without external aid are to be tested to the Surveyor's satisfaction.

2.3.19 Ballast control and indicating systems, along with audible and visual alarms, are to be examined and tested at both the main control station and each of the independent local control stations.

2.3.20 For self-elevating units, the jacking gear machinery and associated control system, including locking devices, are to be generally examined. A planned cycle is to be agreed with LR for the examination of critical components, i.e., pins, flexible hoses, couplings, gear reducers, etc., at each Annual Survey, supplemented where necessary by NDE, as agreed with LR.

2.3.21 Swivel stack including valves, manifolds and pipe connections are to be generally examined under working conditions, with special attention to damage due to mechanical handling, and all seals are to be checked for tightness. Suitable leakage tests may be carried out at the Surveyor’s discretion.

2.3.22 On a single point mooring installation, automatic warning alarms of load monitoring systems are to be tested.

2.4 Safety and communication systems and hazardous areas

2.4.1 The Surveyor is to be satisfied as to the efficient condition as far as practicable of the following systems, in accordance with Part 7:

(a) Fire and gas alarm indication and control systems.
(b) Systems for broadcasting safety information.
(c) Protection system against gas ingress into safe areas.
(d) Protection system against gas escape in enclosed and semi-enclosed hazardous areas.
(e) Emergency shut-down (ESD) systems.
(f) Ventilation arrangements in hazardous areas around turret, swivel stack and mud processing areas are to be generally examined.
(g) Protection system against flooding including:
    (i) Water detection alarm systems for watertight bracings, columns, pontoons, footings, void watertight spaces and chain lockers.
    (ii) Bilge level detection and alarm systems on column-stabilised units and in machinery spaces on surface type units.
    (iii) Remote operation and indication of watertight doors and hatch covers and other closing appliances.
(h) Verification of the operation of manual and/or automatic doors.
(j) Protection of accommodation areas against the ingress of smoke.

2.4.2 For units where flammable mixtures are or may be present, a general examination of electrical equipment located in hazardous areas and spaces is to be made, to ensure that it is suitable for the application and that the integrity of safe type electrical equipment has not been impaired due to corrosion, missing bolts, etc. Cable runs should be examined so far as can be seen for sheath and armouring defects and to ensure that means of supporting the cable are in good order. Alarms and interlocks associated with pressurised equipment or spaces are to be tested for correct operation, *see also* 2.2.2.

2.4.3 Satisfactory operation of automatic shut-down devices and alarms is to be verified.

2.4.4 Pressure vessels and safety devices are to be subject to surveys in accordance with the requirements of Sections 10 and 17.

2.5 Production and oil storage installations

2.5.1 For units with crude oil bulk storage tanks, in addition to the applicable requirements of 2.1 to 2.4, the following are to be dealt with where applicable:

(a) Examination of oil storage tank openings including gaskets, covers, coamings and screens.
(b) Examination of oil storage tank pressure/vacuum valves and flame screens.
(c) Examination of flame screens on vents to all bunker, oily ballast and oily slop tanks and void spaces, so far as is practicable.
(d) Examination of crude oil storage washing, bunker, ballast and vent piping systems, together with flame arresters and pressure/vacuum valves, as applicable above the upper deck within the oil storage tank area, including vent masts and headers.
(e) Verification that no potential sources of ignition such as loose gear, excessive products in the bilges, excessive vapours, combustible materials, etc., are present in or near the oil storage pump-room and that access ladders are in good condition.
(f) Examination of all pump-room bulkheads for signs of leakage or fractures, and in particular, the sealing arrangements of all penetrations in these bulkheads.
(g) Verification that the pump-room ventilation system is operational, ducting intact, dampers operational and screens are clean.
(h) External examination of the piping and shut-off valves of oil storage tank and oil storage pump-room fixed fire-fighting system.
(j) Verification that the deck foam system and deck deluge system are in good operating condition.
(k) Examination of the condition of all piping systems in the oil storage pump-room so far as is practicable.
(l) Examination so far as is practicable of oil storage, ballast, bilges and stripping pumps for excessive gland seal leakage, verification of proper operation of electrical and mechanical remote operating and shutdown devices and operation of pump-room bilge system, and checking that pump foundations are intact.
(m) Verification that installed pressure gauges on oil discharge lines and level indicator systems are operational.
(n) Verification that at least one portable instrument for measuring flammable vapour concentrations is available, together with a sufficient set of spares and a suitable means of calibration.
(o) Examination of any inert gas system, *see* 2.6.
(p) For units greater than 15 years of age, all ballast tanks adjacent (i.e., with a common plane boundary) to a cargo tank with any means of heating are to be examined. Thickness measurement is to be carried out where considered necessary by the Surveyor. Special consideration may be given by the Surveyor to those tanks or spaces where the coatings are found in GOOD condition, as defined in 1.5, at the previous Intermediate or Special Survey.
(q) For ballast tanks, in areas where substantial corrosion, as defined in 1.5, has been noted, additional measurements are to be carried out in accordance with Tables 3.7.7 to 3.7.15 of the Rules for Ships, as applicable. The survey will not be considered complete until these additional thickness measurements have been carried out.

2.5.2 Safety and communication systems and hazardous areas are to be examined in accordance with 2.4.

2.5.3 For units where the requirements of Ch 2,1.1.14 are applicable, the arrangements for fire protection, detection and extinction are to be examined and are to include:

(a) Verification, so far as is practicable, that no significant changes have been made to the arrangement of structural fire protection.
(b) Verification of the operation of manual and/or automatic doors where fitted.
(c) Verification that fire control plans are properly posted.
(d) Examination, so far as is possible, and testing as feasible, of the fire and/or smoke detection and alarm system(s).
(e) Examination of fire main system, and confirmation that each fire pump, including the emergency fire pump, can be operated separately so that sufficient water can be produced to meet the greatest calculated demand in a credible emergency scenario.
(f) Verification that fire-hoses, nozzles, applicators and spanners are in good working condition and situated at their respective locations.
(g) Examination of fixed fire-fighting systems controls, piping, instructions and marking, checking for evidence of proper maintenance and servicing, including date of last systems tests.
(h) Verification that all portable and semi-portable fire-extinguishers are in their stowed positions, checking for evidence of proper maintenance and servicing, conducting random checks for evidence of discharges containers.
(j) Verification, so far as is practicable, that the remote control for stopping fans and machinery and shutting off fuel supplies in machinery spaces and, where fitted, the remote controls for stopping fans in accommodation spaces and the means of cutting off power to the galley are in good working order.
(k) Examination of the closing arrangements of ventilators, funnel annular spaces, skylights, doorways and tunnels, where applicable.
(l) Verification that the fireman's outfits are complete and in good condition.
(m) Examination of the electrical installation in areas which may contain flammable gas or vapour and/or combustible dust to verify that it is in good condition and has been properly maintained.

2.5.4 For units with production and process plant in which Pt 7, Ch 3 applies, the arrangements for fire protection, detection and extinction are to be examined and are to include the applicable requirements of 2.5.3. In addition, the passive fire protection systems to the topsides process modules and associated plant shall be examined to verify, so far as practicable, that no significant changes have been made to the arrangement of structural fire protection.

2.5.5 In addition to the applicable requirements of 2.1 to 2.4, for units with a process plant facility having a **PPF** notation, the Owner is to submit to LR a planned procedure for maintenance and inspection of the process plant facility for review and agreement by LR from the Survey aspects in advance of the first survey, *see* Ch 2,3.5.12. A copy is to be kept on board and made available to the Surveyor. The planned surveys and procedures as agreed by LR will be subject to revision if found necessary at subsequent surveys or when required by the Surveyor.

2.5.6 The Surveyor is to be satisfied as far as is practicable as to the efficient condition of the following components to the process plant facility referred to in 2.5.5 as applicable, *see also* Pt 3, Ch 8:

- Major equipment and structures of the production and process plant.
- Oil or gas processing system.
- Production plant safety systems.
- Production plant utility systems.
- Relief and flare system.
- Well control system.
- Pressure vessels are to be subject to survey in accordance with the requirements of Section 17, *see also* 2.5.7.

2.5.7 Selected pressure safety valves are to be bench tested in accordance with a planned procedure for maintenance and inspection, *see* 2.5.5.

2.5.8 If the process plant facility is not classed but is certified by LR or another acceptable organisation, the survey and maintenance records of the process plant are to be made available to the Surveyor, who is to ensure that the records are up to date with no outstanding items which could affect the safety of the unit.

2.6 Inert gas systems

2.6.1 For inert gas systems, where fitted, the following are to be dealt with:

(a) External examination of the condition of piping, including vent piping, above the upper deck in the crude oil storage tank area and overboard discharges through the shell as far as practicable, together with components for signs of corrosion or gas leakage/effluent leakage.
(b) Verification of the proper operation of both inert gas blowers.
(c) Checking the scrubber room ventilation system.
(d) Checking, so far as is practicable, of the deck water seal for automatic filling and draining and checking for presence of water carry-over. Checking the operation of the non-return valve.
(e) Testing of all remotely operated or automatically controlled valves including the flue gas isolating valve(s).
(f) Checking the interlocking features of soot blowers.
(g) Checking the gas pressure regulating valve automatically closes when the inert gas blowers are secured.
(h) Checking, so far as is practicable, the following alarms and safety devices of the inert gas system, using simulated conditions where necessary:
    (i) High oxygen content of gas in the inert gas main.
    (ii) Low gas pressure in the inert gas main.
    (iii) Low pressure in the supply to the deck water seal.
    (iv) High temperature of gas in the inert gas main.
    (v) Low water pressure to the scrubber.
    (vi) Accuracy of portable and fixed oxygen measuring equipment by means of calibration gas.
(j) Checking of the interlocking features and positive isolation for tank isolation.

2.7 Drilling units

2.7.1 In addition to the applicable requirements of 2.1 to 2.4, for units having a **DRILL** notation, the Owner is to submit to LR a planned procedure for maintenance and inspection of the drilling plant facility for review and agreement by LR from the survey aspect in advance of the first survey, *see* Ch 2,3.5.12. A copy is to be kept on board and made available to the Surveyor. The planned surveys and procedures as agreed by LR will be subject to revision if found necessary at subsequent surveys or when required by the Surveyor.

2.7.2 The Surveyor is to be satisfied as far as is practicable as to the efficient condition of the following components of the drilling plant facility referred to in 2.7.1, as applicable, *see also* Pt 3, Ch 7:

- Blow out preventer hoisting and handling equipment.
- Blow out preventer, diverter and their control systems.
- Choke manifold and associated valves.
- Bulk storage.
- Drilling fluids circulation and cementing equipment.
- Drilling derrick and hoisting, rotation and pipe handling equipment.
- Heave compensation equipment.
- Miscellaneous drilling equipment and equipment considered as part of the drilling installation.
- Well testing equipment.
- Well protection valve and control systems.

2.7.3 Safety and communication systems and hazardous areas are to be examined in accordance with 2.4.

2.7.4 Pressure vessels forming part of the drilling plant facility are to be subject to surveys in accordance with the requirements of Section 17, *see also* 2.7.5.

2.7.5 Selected pressure safety valves are to be bench tested in accordance with a planned procedure for maintenance and inspection, *see* 2.7.1.

2.7.6 If a drilling plant facility is not classed but is certified by LR or another acceptable organisation, the survey and maintenance records of the drilling plant are to be made available to the Surveyor, who is to ensure that the records are up to date with no outstanding items which could affect the safety of the unit.

Section 3
Intermediate Surveys – Hull and machinery requirements

3.1 General

3.1.1 Intermediate Surveys are to be held concurrently with statutory annual or other relevant statutory surveys wherever practicable.

3.2 Intermediate Surveys

3.2.1 The requirements of Section 2 are to be complied with, so far as applicable.

3.2.2 A general examination of salt-water ballast spaces is to be carried out by the Surveyor as required by 3.2.5 and 3.2.6. If such examinations reveal no visible structural defects, the examination may be limited to a verification that the protective coating remains in GOOD or FAIR condition, as defined in 1.5. When considered necessary by the Surveyor, thickness measurement of the structure is to be carried out.

3.2.3 For salt-water ballast tanks, other than independent double bottom tanks, where a protective coating is found to be in POOR condition, as defined in 1.5, and it has not been repaired, where a soft or semi-hard coating has been applied or where a protective coating was not applied from the time of construction, maintenance of class will be subject to the spaces in question being internally examined and gauged as necessary at Annual Surveys.

3.2.4 For independent salt-water double bottom tanks where a protective coating is found to be in POOR condition, as defined in 1.5, and it has not been repaired, where a soft or semi-hard coating has been applied or where a protective coating was not applied from the time of construction, maintenance of class may, at the discretion of the Classification Committee, be subject to the spaces in question being examined and gauged as necessary at Annual Surveys.

3.2.5 For all units over five years of age and up to 10 years of age, representative salt-water ballast tanks and other spaces are to be examined as follows:

- **Column-stabilised units and tension-leg units**
  Representative ballast tanks in pontoons, lower hulls, and free-flooding compartments as accessible, and at least two ballast tanks in columns and upper hull, if applicable.
- **Self-elevating units**
  Representative ballast tanks and at least two representative pre-load tanks. Accessible free-flooding compartments in mat or footings.
- **Ship units**
  One peak tank and at least two other representative ballast tanks between the peak bulkheads used primarily for water ballast.
- **Deep draught caissons**
  Representative ballast tanks where accessible.
- **All unit types**
  Particular attention is to be given to corrosion control systems in ballast tanks, free-flooding areas and other locations subjected to sea-water from both sides where accessible.

For tanks other than independent double bottom tanks, where a protective coating is found in POOR condition, as defined in 1.5, or other defects are found, where a soft or semi-hard coating has been applied or where a protective coating was not applied from the time of construction, the examination is to be extended to other ballast tanks of the same type. For independent double bottom tanks where substantial corrosion or other defects are found, the examination is to be extended to other ballast tanks of the same type.

3.2.6 For all unit types over 10 years of age, the following is required:

(a) All salt-water ballast tanks and free-flooding areas are to be examined.
(b) The anchors on units assigned the character **(1)** are to be partially lowered and raised using the windlass.

3.2.7 The Surveyor is to carry out an examination and thickness measurement of structure identified at the previous Special Survey as having substantial corrosion, *see* Section 5.

3.2.8 In addition to 3.2.1 to 3.2.7 on units with crude oil bulk storage tanks, the following are to be dealt with where applicable:

(a) An examination of oil storage, crude oil washing, bunker, ballast, steam and vent piping on weather decks, as well as vent masts and headers. If, upon examination, there is any doubt as to the condition of the piping, the piping may be required to be pressure tested, gauged, or both.
(b) A general examination within the areas deemed as dangerous, such as cargo pump-rooms and spaces adjacent to and zones above cargo tanks, for defective and non-certified safe type electrical equipment, improperly installed, defective and dead-end wiring. An electrical insulation resistance test of the circuits terminating in, or passing through, the dangerous areas is to be carried out. If the unit is not in a gas-free condition, the results of previously recorded test readings may be accepted.

3.2.9 For all units, the electrical generating sets are to be examined under working conditions to verify compliance with Pt 6, Ch 2,2.2.

3.2.10 The following are to be examined where accessible:

- Turret and circumturret structure.
- Turret bearings and seals.
- Swivel stack bearings and seals.
- Mooring arm pivots and bearings.

3.2.11 For units with crude oil bulk storage tanks, in addition to 3.2.6, the following is required for units over 10 years and less than 15 years of age:

(a) Overall survey of all salt-water ballast tanks, including any combined salt-water ballast/crude oil storage tanks.
(b) Overall survey of at least two representative crude oil storage tanks.

(c) Close-up Survey of salt-water ballast tanks to the same extent as the previous Special Survey and two combined cargo/ballast tanks. Where protective coatings are found to be in GOOD condition, as defined in 1.5, the extent of Close-up Survey may be specially considered.
(d) The thickness measurement requirements of 3.2.7 are to be complied with. In areas where substantial corrosion, as defined in 1.5, has been noted, additional measurements are to be carried out to the satisfaction of the Surveyor. The survey will not be considered complete until these additional thickness measurements have been carried out.
(e) Machinery and boiler spaces, including tank tops, bilges and cofferdams, sea suctions and overboard discharges, are to be generally examined.

3.2.12 For units with crude oil bulk storage tanks, in addition to 3.2.8 and 3.2.11, the following is required for units over 15 years of age:
(a) A survey to the same extent as the previous Special Survey (applicable only to ESP surveys, *see* Pt 1, Ch 3,7.1.2 of the Rules for Ships).
(b) Pressure testing of cargo and ballast tanks is to be carried out if deemed necessary by the attending Surveyor.

■ *Section 4* Docking Surveys and In-water Surveys – Hull and machinery requirements

4.1 General

4.1.1 At Docking Surveys or In-water Surveys in lieu of Docking Surveys, the Surveyor is to examine the unit and machinery, so far as necessary and practicable, in order to be satisfied as to the general condition, *see also* Ch 2,3.5.3.

4.2 Docking Surveys

4.2.1 Where a unit is in dry dock or on a slipway, it is to be placed on blocks of sufficient height, and proper staging is to be erected as may be necessary, for the examination of the shell, including bottom and bow plating, keel, sponsons and appendages, stern, sternframe and rudder. The rudder is to be lifted for examination of the pintles if considered necessary by the Surveyor.

4.2.2 For self-elevating units, the leg footings and those parts of the leg and hull that are normally under water are to be examined. The connections between leg chords and the footings or mats are to be inspected and subjected to NDE.

4.2.3 For self-elevating units, at each Docking Survey or equivalent coinciding with Special Survey, the Surveyor is to be satisfied with the internal condition of the leg footings or mats.

4.2.4 For column-stabilised units, external surfaces of the upper hull or platform, footings, pontoons or lower hulls, underwater areas of columns, bracing and their connections, sea chests, and propulsion units as applicable, are to be selectively cleaned and examined to the satisfaction of the attending Surveyor. Non-destructive testing may be required of areas considered to be critical or found to be suspect by the Surveyor.

4.2.5 The shell plating is to be examined for excessive corrosion, deterioration due to chafing or contact with the ground and for undue unfairness or buckling. Special attention is to be given to the connections between the bilge strakes and bilge keels.

4.2.6 The external cathodic protection system and coatings are to be examined.

4.2.7 The clearances in the rudder bearings are to be measured. Where applicable, pressure testing of the rudder may be required if deemed necessary by the Surveyor.

4.2.8 The sea connections and overboard discharge valves and cocks and their attachments to the hull are to be examined.

4.2.9 Thrusters, propeller, sternbush and sea connection fastenings and the gratings at the sea inlets are to be examined.

4.2.10 The clearance in the sternbush or the efficiency of the oil glands is to be ascertained.

4.2.11 When chain cables are ranged, the anchors and cables are to be examined by the Surveyor, *see also* 5.3.26. For units having a positional mooring notation in accordance with Pt 3, Ch 10, the positional mooring systems and associated equipment are also to be examined.

4.2.12 For electrical equipment survey requirements of units five years old and over, *see* 9.3.

4.3 In-water Surveys

4.3.1 When it is not practicable to dry-dock a unit or when an Owner does not intend to dry-dock a unit during its normal service life, the Committee will accept an In-water Survey in lieu of docking on units where an **OIWS** notation is assigned, *see* Ch 2,2.4.13.

4.3.2 Special arrangements must be incorporated into the unit's design or otherwise provided to allow adequate survey of thrusters, stern bearings, rudder bearings, sea suctions and valves, etc., *see* Pt 3, Ch 1,2.1.3.

4.3.3 Special consideration shall be given to ascertaining rudder bearing clearances and sternbush clearances, based on a review of the operating history, onboard testing and stern bearing oil analysis. These considerations are to be included in the proposals, *see* 4.3.5.

4.3.4 The In-water Survey is to provide the information normally obtained from the Docking Survey, so far as practicable.

4.3.5 Proposals for In-water Surveys are to be submitted in advance of the survey being required so that satisfactory arrangements can be agreed with LR.

4.3.6 A planned procedure for the routine inspection of the underwater areas is to be agreed between the Owners and LR. A procedure document is to be placed on board the unit and made available to the Surveyor. Where survey experience indicates that modifications are required to the inspection procedures, the procedure document is to be modified to the satisfaction of LR.

4.3.7 The In-water Survey is to be carried out at an agreed geographical location under the surveillance of a Surveyor to LR, with the unit at a suitable draught in sheltered waters and with weak tidal streams and currents. The in-water visibility is to be good and the hull below the waterline is to be clean. The Surveyor is to be satisfied that the method of pictorial presentation is satisfactory. There is to be good two-way communication between the Surveyor and the diver/ROV operator.

4.3.8 In general, the In-water Survey is to be carried out by an approved diving company with suitably qualified divers. Alternatively, the In-water Survey may be carried out using a suitable ROV, subject to agreement with the attending LR Surveyor. The ROV should be fitted with suitable cameras, transmission and recording facilities.

4.3.9 The efficient condition of the cathodic protection system and the high resistance paint is to be confirmed at each In-water Survey to the satisfaction of the Surveyors, in order that the **OIWS** notation can be maintained.

4.3.10 If the In-water Survey reveals damage or deterioration that requires early attention, the Surveyor may require that the unit be dry-docked, in order that a more detailed survey can be undertaken and the necessary work carried out.

4.3.11 Diver/ROV-assisted surveys are not acceptable for the periodic survey inspections of primary bracing members, or intersections of bracings with columns or pontoons, or column to pontoon intersections on column-stabilised units, except in exceptional circumstances when specially agreed with the Classification Executive and the procedures have been approved, *see also* 2.2.3.

4.3.12 Turret and bearings below water level, underwater parts of mooring towers and/or articulated towers (where applicable), chain stoppers, chain cables and mooring lines/chains are to be examined as far as practicable during In-water Surveys. On tension-leg units, tethers and their upper and lower connections are to be examined.

4.3.13 For electrical equipment survey requirements of units five years old and over, *see* 9.3.

4.3.14 Some National Administrations may have requirements additional to those of 4.3.1 to 4.3.13.

4.3.15 For self-elevating units, the requirements of 4.2.2 and 4.2.3 are to be undertaken as far as practicable with due consideration to the operation and location of the unit.

■ *Section 5*
Special Survey – Hull requirements

5.1 General

5.1.1 The survey is to be of sufficient extent to ensure that the hull/structure and related piping is in satisfactory condition and is fit for its intended purpose, subject to proper maintenance and operation and to periodical surveys being carried out as required by the Regulations.

5.1.2 The examination is to be sufficient to ascertain substantial corrosion, significant deformation, fractures, damages or other structural deterioration and, if deemed necessary by the Surveyor, suitable non-destructive examination may be required.

5.1.3 The approved Planned Survey Programme, as indicated in 1.6, is to be followed for all units.

5.1.4 The requirements of Section 2 are to be complied with, as applicable, for all units.

5.1.5 A Docking Survey, or an In-water Survey in lieu of a Docking Survey, in accordance with the requirements of Section 4 is to be carried out as part of the Special Survey.

5.1.6 **Surface type units**. The requirements of Pt 1, Ch 3,7 of the Rules for Ships are to be complied with, as applicable.

5.2 Preparation

5.2.1 The unit is to be prepared as necessary for the Surveyors to gain proper access for the careful inspection and examination of all items listed in this Section. Voids and closed spaces are to be thoroughly ventilated to ensure adequate levels of oxygen in the air, fuel tanks, oil storage tanks and other similar spaces are to be gas freed and cleaned as necessary and paint lining, insulation and other coatings and coverings are to be removed locally if required by the Surveyors.

5.2.2 In cases where the inner surface of the bottom plating is covered with cement, asphalt, or other composition, the removal of this covering may be dispensed with, provided that it is inspected, tested by beating and chipping and found sound and adhering satisfactorily to the steel.

5.2.3 **Surface type units**. The requirements of Pt 1, Ch 3.5.2 of the Rules for Ships are to be complied with, as applicable.

5.3 Examination and testing

5.3.1 All spaces within the hull/structure and superstructure are to be subject to an overall survey and examination.

5.3.2 Watertight integrity of tanks, bulkheads, hull, decks and other compartments is to be verified by visual inspection.

5.3.3 **Surface type units**. The requirements of Pt 1, Ch 3,5.3 of the Rules for Ships are to be complied with, as applicable. Testing of crude oil storage tanks is to be carried out as deemed necessary by the attending Surveyor.

5.3.4 For tank internal examinations, the requirements of Pt 1, Ch 3,5.3.2 of the Rules for Ships are to be complied with as applicable.

5.3.5 In spaces used for salt-water ballast, excluding double bottom tanks, where a protective coating is found in POOR condition, as defined in 1.5, and it has not been repaired, where a soft or semi-hard coating has been applied or where a protective coating was not applied from the time of construction, maintenance of class will be subject to the space in question being internally examined and gauged as necessary at Annual Surveys.

5.3.6 For independent salt-water double bottom tanks where a protective coating is found to be in POOR condition, as defined in 1.5, and it has not been repaired, where a soft or semi-hard coating has been applied or where a protective coating was not applied from the time of construction, maintenance of class may, at the discretion of the Classification Committee, be subject to the spaces in question being examined and gauged as necessary at Annual Surveys.

5.3.7 Double bottom, deep, ballast, peak and other tanks, including cargo holds assigned also for the carriage of salt-water ballast, are to be tested with a head of liquid to the top of air pipes or to the top of hatches for ballast/cargo holds. Boundaries of oil fuel, lubricating oil and fresh water tanks are to be tested with a head of liquid to the maximum filling level of the tank. Tank testing of oil fuel, lubricating oil and fresh water tanks may be specially considered, based upon a satisfactory external examination of the tank boundaries, and a confirmation from the Master stating that the pressure testing has been carried out according to the requirements with satisfactory results.

5.3.8 Where repairs are effected to the shell plating or bulkheads, any tanks in way are to be tested to the Surveyor's satisfaction on completion of these repairs.

5.3.9 In units with crude oil storage tanks, all piping systems on deck and within the storage tanks and adjacent spaces are to be examined to ensure that tightness and condition remain satisfactory. Special attention is to be given to ballast piping in storage tanks and crude oil storage piping in ballast tanks, pump-rooms, pipe tunnels and void spaces.

5.3.10 Where substantial corrosion, as defined in 1.5, is identified in crude oil storage tanks and is not rectified, this will be subject to re-examination at Annual and Intermediate Surveys and is to be gauged as necessary.

5.3.11 At the first Special Survey and at subsequent Special Surveys, representative tanks are to be examined by a Close-up Survey. The extent of the survey is to be agreed with LR in advance of the survey.

5.3.12 The attachment to the structure and condition of anodes in all tanks is to be examined.

5.3.13 In addition to the requirements of 5.3.1, column-stabilised units and tension-leg units are to have a complete bracing Close-up Survey consisting of a detailed dry examination of all bracings and their structural connections to columns and decks. The connections of columns to lower hulls, pontoons and upper hulls are to be examined. All critical regions defined in 2.2.3 are to be examined by approved methods of NDE, *see also* Ch 2,3.5.12. Primary structure of the upper hull or platform which form 'Box' or 'I' type supporting structure and their end connections are to be examined. All free-flooding areas and sponsons are to be examined.

5.3.14 In addition to the requirements of 5.3.1, self-elevating units are to have a complete survey of all legs, footings and mats. Particular attention is to be given to the leg structure in way of the waterline. Tubular or similar type legs are to be examined externally and internally, including stiffeners and pin holes. All critical regions defined in 2.2.4 are to be examined by approved methods of NDE, including the leg connections to footings or mats, *see also* Ch 2,3.5.12. Jetting piping systems or other external piping, particularly where penetrating footings or mats, are to be examined.

5.3.15 In addition to the requirements of 5.3.1, surface type units are to have a Close-up Survey carried out in accordance with an agreed programme, *see also* 1.6.1. The programme should identify all critical areas of primary structure components and connections within compartments to be surveyed. Special attention is to be given to underdeck structure supporting topside equipment, flare stack and cranes, etc. The Surveyor may extend the Close-up Survey if deemed necessary, taking into account the maintenance of the tanks under survey and the condition of the corrosion prevention system. For areas in tanks where coatings are found to be in GOOD condition, as defined in 1.5.12, the extent of Close-up Survey may be specially considered.

5.3.16 In addition to the requirements of 5.3.1, structural appendages and ducts for positioning units, sponsons and positioning spuds on surface type units are to be examined.

5.3.17 On all units, careful examination is to be made of those parts of the structure particularly liable to excessive corrosion, or to deterioration or damage from causes such as chafing, lying on the sea bed or handling of drilling equipment, stores, etc., and due to water collection in corners of bulkheads and on weather decks, and in other exposed areas.

5.3.18 All decks including helidecks and their supporting structure, deck-houses, casings and superstructures are to be examined. Where aluminium alloy is used in the structure, bimetallic joints are to be examined as far as practicable. Lifeboat and winch platforms and their supporting structures are to be examined.

5.3.19 Wood decks and sheathing are to be examined. If decay or rot is found or the wood is excessively worn, the wood is to be renewed. Attention is to be given to the condition of the plating under wood decks, sheathing or other deck covering. If it is found that such coverings are broken, or are not adhering closely to the plating, sections are to be removed as necessary to ascertain the condition of the plating, *see also* 1.2.1.

5.3.20 Primary bulkheads in the upper hull of column-stabilised units and in the hull of self-elevating units are to be examined. Particular attention is to be given to the structure below and derrick sub-structures and supports under process plant, drilling derricks and other heavy equipment. Bulkheads adjacent to leg wells, turrets and moonpools are to be examined. Bulkhead penetrations in way of doors and other openings are to be examined.

5.3.21 A Close-up Survey of structure around external and internal turrets is to be held as per an agreed planned survey programme. Thickness measurements are to be made as per the agreed planned survey programme, *see* Pt 1, Ch 2,3.5.12. Turret bearings are to be examined in accordance with the manufacturers' recommendations and agreed survey programme. Records of analyses of turret and swivel bearing seals and lubricants are to be examined by the Surveyors for compliance to manufacturers' standards and/or recommendations.

5.3.22 Mooring buoys, mooring arms and yokes, mooring towers, and other similar special features of the installation are to be specially examined in accordance with an agreed planned survey programme.

5.3.23 For deep draught caisson units having combined oil/ballast tanks which for operational requirements are always full, the periodic survey programme is to be agreed to at the design stage. Owners may consider installing suitable steel coupon plates in these tanks, where practicable, to monitor corrosion. Where coupon plates are fitted, their position will be specially considered and they are to be electrically insulated from the unit. Weight and thickness of the coupon plates are to be recorded and reported at each special survey.

5.3.24 For tension-leg units, a Close-up Survey of the structure in way of tethers is to be carried out.

5.3.25 For units having a **DRILL** notation, the drilling derrick, including bolting arrangements is to be examined. Other structural components and supports forming part of the drilling plant are to be examined and tested as necessary, *see also* 2.7.

5.3.26 The anchors are to be examined. If the chain cables are ranged, they are to be examined. If any length of chain cable is found to be reduced in mean diameter at its most worn part by 12 per cent or more from its nominal diameter, it is to be renewed. The windlass is to be examined. For equipment forming part of a positional mooring system, *see* 5.5.

5.3.27 For production units with a process plant facility having a **PPF** notation, all plant supporting structure including bracing trusses and skids is to be examined, *see also* 2.5.6.

5.3.28 The requirements for thickness determination of the structure of all unit types are to be in accordance with 5.4.

5.3.29 Crane pedestals and similar supporting structures to access gangways and flare booms, masts and standing rigging are to be examined.

5.3.30 At the second Special Survey and subsequent Special Surveys, chain lockers are to be cleaned and examined internally.

5.3.31 For disconnectable units assigned the character figure **(1)**, anchors are to be examined. Anchors are to be partially lowered and raised by the windlass or winch as applicable. The chain cables and wire rope cables are to be examined as far as practicable. If any length of chain cable is found to be reduced in mean diameter at its most worn part by 12 per cent or more from its nominal diameter, it is to be renewed. The anchor windlass or winch is to be examined. For equipment forming part of a positional mooring system, *see* 5.5.

5.3.32 The hand pumps, suctions, watertight doors, air and sounding pipes are to be examined. In addition, the Surveyor is to examine internally air pipe heads in accordance with the requirements of Table 3.5.1.

5.3.33 The Surveyor is to be satisfied as to the efficient condition of the helm indicator, protection of aft steering wheel and gear on self-propelled units.

5.3.34 Foundations and supporting headers, brackets and stiffeners for drilling-related apparatus, where attached to hull, deck, substructure or deck-house, are to be examined.

5.3.35 Foundations of machinery are to be examined.

5.4 Thickness measurement

5.4.1 The requirements for thickness measurements given in 1.8 are to be complied with.

5.4.2 In addition to the thickness measurements required by 5.4.1 to ascertain local wastage, thickness measurement is to be carried out on units with crude oil bulk storage tanks at the first Special Survey and at subsequent Special Surveys, in accordance with the requirements of Pt 1, Ch 3,5.6 and Pt 1, Ch 3,7.7 of the Rules for Ships, as applicable.

Table 3.5.1 Air pipe head internal examination requirements (applicable for automatic air pipe heads installed on exposed decks of all units)

Special Survey I (Units 5 years old)	Special Survey II (Units 10 years old)	Special Survey III (Units 15 years old) and subsequent
(1) Two air pipe heads (one port and one starboard) on exposed decks in the forward 0,25*L*. *See* Notes 1 to 5 (2) Two air pipe heads (one port and one starboard) on the exposed decks, serving spaces aft of 0,25*L* *See* Notes 1 to 5	(1) All air pipe heads on exposed decks in the forward 0,25*L*. *See* Notes 1 to 5 (2) At least 20% of air pipe heads on exposed decks, serving spaces aft of 0,25*L*. *See* Notes 1 to 5	All air pipe heads on exposed decks. *See* Notes 1 to 6

NOTES
1. Air pipe heads serving ballast tanks are to be selected where available.
2. The Surveyor is to select which air pipe heads are to be examined.
3. Where considered necessary by the Surveyor as a result of the examinations, the extent of examinations may be extended to include other air pipe heads on exposed decks.
4. Where the inner parts of an air pipe head cannot be properly examined due to its design, it is to be removed in order to allow an internal examination.
5. Particular attention is to be given to the condition of the zinc coating in heads constructed from galvanised steel.
6. Exemption may be considered for air pipe heads where there is documented evidence of their replacement within the previous five years.

5.4.3 On all other unit types, thickness measurement is required at the second Special Survey and at subsequent Special Surveys. Thickness measurement of the primary hull structure is to include the shell plating of hulls, pontoons, columns, bracings, main strength decks, bulkheads, legs, footings, mats and the structure of representative salt-water ballast and pre-load tanks and other tanks and critical areas as required by the Surveyor, to determine the amount of any general diminution in thickness. The extent and location of such measurements are to be agreed by LR prior to each survey, *see also* 1.6.1.

5.5 Positional mooring systems

5.5.1 On units fitted with positional mooring equipment which have been assigned a special features notation in accordance with Pt 3, Ch 10, the requirements for annual surveys in 2.2.11 are to be complied with.

5.5.2 Where practicable, mooring cables, chains and anchors are to be lifted to the surface for detailed inspection in accordance with 5.5.3 and 5.5.4 at each Special Survey. Alternatively, *in situ* inspection, using acceptable techniques, will be considered by LR when requested. *See also* Pt 3, Appendix B for guidance notes on the inspection of positional mooring systems.

5.5.3 As far as practicable, the Surveyor is to determine the general condition of the mooring system, including cables, chains, fibre ropes, fittings, fairleads, connections and equipment. Particular attention is to be given to the following:
- Cable or chain in contact with fairleads, etc.
- Cable or chain in way of winches and stoppers.
- Cable or chain in way of the splash zone.
- Cable or chain in the contact zone of the sea bed.
- Damage to mooring system.
- Extent of marine growth.
- Condition and performance of corrosion protection.

5.5.4 Anchors are to be cleaned and examined. Wire rope anchor cables are to be examined. If cables are found to contain broken, badly corroded or bird caging wires, they are to be renewed. Chain cables are to be ranged and examined. Maximum acceptable diminution of anchor chain in service will normally be limited to a two per cent reduction from basic chain diameter (basic chain diameter can be taken as the diameter, excluding any design corrosion allowance, which satisfies the Rule requirement for minimum factors of safety).

5.5.5 The windlasses or winches are to be examined.

5.5.6 Structure in way of anchor racks and anchor cable fairleads is to be examined.

■ *Section 6* Machinery Surveys – General requirements

6.1 Annual, Intermediate, Docking and In-water Surveys

6.1.1 For Annual, Intermediate, Docking and In-water Surveys, *see* Sections 2, 3 and 4.

6.1.2 For laid-up machinery, *see* Section 20.

6.2 Complete Surveys

6.2.1 While the unit is in dry dock or subject to In-water Surveys, all openings to the sea in the machinery spaces, pump-rooms and other spaces, together with the valves, cocks and the fastenings with which these are connected to the hull, are to be examined and the fastenings to the shell plating are to be renewed when considered necessary by the Surveyor.

6.2.2 All shafts (except screwshafts and tube shafts, for which special arrangements are detailed in Section 12), thrust block and all bearings are to be examined. The lower halves of bearings need not be exposed if alignment and wear are found to be acceptable.

6.2.3 An examination is to be made of all reduction gears, complete with all wheels, pinions, shafts, bearings and gear teeth, thrust bearings and incorporated clutch arrangements.

6.2.4 The following auxiliaries and components are also to be examined:

(a) Auxiliary engines, auxiliary air compressors with their intercoolers, filters and/or oil separators and safety devices, and all pumps and components used for essential services.
(b) Steering machinery.
(c) Windlass and mooring winches and associated driving equipment, where fitted.
(d) Evaporators (other than those of vacuum type) and their safety valves, which should be seen in operation under steam.
(e) The holding-down bolts and chocks of main and auxiliary engines, gearcases, thrust blocks and intermediate shaft bearings.

6.2.5 All air receivers for essential services, together with their mountings, valves and safety devices, are to be cleaned internally and examined internally and externally. If internal examination of the air receivers is not practicable, they are to be tested hydraulically to 1,3 times the working pressure.

6.2.6 The valves, cocks and strainers of the bilge system, including bilge injection, are to be opened up as considered necessary by the Surveyor and, together with pipes, are to be examined and tested under working conditions. The oil fuel, feed, lubricating oil and cooling water systems, also the ballast connections and blanking arrangements to deep tanks, pre-load tanks or brine tanks which may carry different liquid, together with all pressure filters, heaters and coolers used for essential services, are to be opened up and examined or tested, as considered necessary by the Surveyor. All safety devices for the foregoing items are to be examined.

6.2.7 Fuel tanks which do not form part of the unit's structure are to be examined, and if considered necessary by the Surveyor, they are to be tested to the pressure specified for new tanks. The tanks need not be examined internally at the first survey if they are found satisfactory on external inspection. The mountings, fittings and remote controls of all oil fuel tanks are to be examined, so far as is practicable.

6.2.8 Arrangements are to be made by Owners for opening up and examination of all sea connections afloat at five-yearly intervals.

6.2.9 Where remote and/or automatic controls are fitted for essential machinery, they are to be tested to under operating conditions to an approved test scheule.

6.2.10 On units fitted with a dynamic positioning system and/or thruster-assisted positional mooring system, the control system and associated machinery items, including pressure vessels, are to be examined and tested to demonstrate that they are in good working order.

6.2.11 In addition to the above, detailed requirements for steam and gas turbines, oil engines, electrical installations and boilers are given in Sections 7, 8, 9 and 10 respectively. In certain instances, upon application by the Owner or where indicated by the maker's servicing recommendations, the Classification Committee will give consideration to the circumstances where deviation from these detailed requirements is warranted, taking account of design, appropriate indicating equipment (e.g., vibration indicators) and operational records.

6.2.12 For self-elevating units, the following essential parts of the elevating and lowering machinery, which are critical to the safety of the unit, are to be specially examined:

(a) Couplings, pinions and gears of the climbing pinion gear train of rack and pinion systems are to be examined and NDE is to be carried out to the Surveyor's satisfaction.
(b) Attachment of the reduction gear case to the jackcases or other supporting structure is to be examined for wear and bolting arrangements examined for security.
(c) Leg guides and shock pads are to be examined for wear.
(d) The fixation system, where fitted, is to be examined for wear and satisfactory operation/engagement.
(e) Grease injection lubrication system is to be examined for damage to piping and nozzles. Satisfactory operation of system is to be verified.
(f) Operational tests of the jacking system are to be carried out to the Surveyor's satisfaction.

6.2.13 Where an approved planned maintenance scheme is in operation, surveys may be carried out in accordance with Ch 2,3.5.21 and 3.5.22.

■ *Section 7* Turbines – Detailed requirements

7.1 Complete Surveys

7.1.1 The requirements of Section 6 are to be complied with.

7.1.2 The working parts of the main engines and attached pumps, and of auxiliary machinery used for essential services, are to be opened out and examined, including:

- For turbine machinery:
  Bulkhead stop valves and manoeuvring valves.
  Blading and rotors.
  Flexible couplings.
  Casings.

7.1.3 In gas turbines and free piston gas generators, the following parts are also to be opened out and examined:

- Impellers or blading.
- Rotors and casings of the air compressors.
- Combustion chambers and burners.
- Intercoolers and heat exchangers.
- Gas and air piping, and fittings.
- Starting and reversing arrangements.

7.1.4 Where gas turbines operate in conjunction with free piston gas generators, the following parts of the latter are to be opened out and examined:

- Gas and air compressor cylinders and pistons.
- Compressor end covers.
- Valves and valve gear.
- Fuel pumps and fittings.
- Synchronising and control gear.
- Cooling system.
- Explosion relief devices.
- Gas and air piping.
- Receivers and valves, including bypass arrangements.

7.1.5 Condensers, steam reheaters, desuperheaters which are not incorporated in the boilers, and any other appliances used for essential services, are to be examined to the satisfaction of the Surveyor, and if it is considered necessary, they are to be tested.

7.1.6 The manoeuvring of the engines is to be tested under working conditions.

7.1.7 Exhaust steam turbines supplying power for main propulsion purposes, together with their gearing and appliances, steam compressors or electrical machinery, are to be examined, so far as is practicable. Where cone connections to internal gear shafts are fitted, the coned ends are to be examined, so far as is practicable.

7.1.8 In units having essential auxiliary machinery driven by oil engines, the prime movers of these auxiliaries are to be examined as detailed in Section 8.

■ *Section 8*
Oil engines – Detailed requirements

8.1 Complete Surveys

8.1.1 The requirements of Section 6 are to be complied with.

8.1.2 The following parts are to be opened out and examined:

- Cylinders and covers.
- Pistons, piston rods, connecting rods, crossheads and guides.
- Valves and valve gear.
- Crankshafts and all bearings.
- Crankcases, bedplates and entablatures.
- Crankcase door fastenings, explosion relief devices and scavenge relief devices.
- Scavenge pumps, scavenge blowers, superchargers and their associated coolers.
- Air compressors and their intercoolers.
- Filters and/or separators and safety devices.
- Fuel pumps and fittings.
- Camshaft drives and balancer units.
- Vibration dampers or detuners.
- Flexible couplings and clutches.
- Reverse gears.
- Attached pumps and cooling arrangements.

8.1.3 Selected pipes in the starting air system are to be removed for internal examination and are to be hammer tested. If any appreciable amount of lubricating oil is found in the pipes, the starting air system is to be thoroughly cleaned internally by steaming out, or other suitable means. Some of the pipes selected are to be those adjacent to the starting air valves at the cylinders and to the discharges from the air compressors.

8.1.4 The electric ignition system, if fitted, is to be examined and tested.

8.1.5 The manoeuvring of engines is to be tested under working conditions. Initial starting arrangements are to be tested.

8.1.6 Where steam is used for essential purposes, the condensing plant, feed pumps and oil fuel burning plant are to be examined and the steam pipes examined and tested as detailed in Section 11.

■ *Section 9*
Electrical equipment

9.1 Annual and Intermediate Surveys

9.1.1 The requirements of Sections 2 and 3 are to be complied with as far as applicable.

9.2 Complete Surveys

9.2.1 An electrical insulation resistance test is to be made on the electrical equipment and cables. The installation may be subdivided, or equipment which may be damaged disconnected, for the purpose of this test.

9.2.2 The fittings on the main and emergency switchboard, section boards and distribution boards are to be examined and over-current protective devices and fuses inspected to verify that they provide suitable protection for their respective circuits.

9.2.3 Generator circuit breakers are to be tested, so far as is practicable, to verify that protective devices, including preference tripping relays, if fitted, operate satisfactorily.

9.2.4 The electric cables are to be examined, so far as is practicable, without undue disturbance of fixtures or casings unless opening up is considered necessary as a result of observation or of the tests required by 9.2.1.

9.2.5 The generator prime movers are to be surveyed as required by Sections 7 and 8 and the governing of the engines tested. The motors concerned with essential services, together with associated control and switch gear, are to be examined and if considered necessary, are to be operated, so far as is practicable, under working conditions. All generators and steering gear motors are to be examined and are to be operated under working conditions, though not necessarily under full load or simultaneously.

9.2.6 Where transformers associated with supplies to essential services are liquid immersed, the Owner is to arrange for samples of the liquid to be taken and tested for breakdown voltage, acidity and moisture by a competent testing authority, and a certificate giving the test results is to be supplied to the Surveyor.

9.2.7 Navigation light indicators are to be tried under working conditions, and correct operation on the failure of supply or failure of navigation lights verified.

9.2.8 The emergency sources of electrical power, their automatic arrangements and associated circuits are to be tested.

9.2.9 Emergency lighting, transitional emergency lighting, supplementary emergency lighting, general emergency alarm and public address systems are to be tested as far as is practicable.

9.2.10 Where the unit is electrically propelled, the propulsion motors, generators, cables and all ancillary electrical gear, exciters and ventilating plant (including coolers) associated therewith are to be examined, and the insulation resistance to earth is to be tested. Special attention is to be given to windings, commutators and slip-rings. The operation of protective gear and alarm devices is to be checked, so far as is practicable. Insulating oil, if used, is to be tested in accordance with 9.2.6. Interlocks intended to prevent unsafe operations or unauthorised access are to be checked to verify that they are functioning correctly. Emergency over-speed governors are to be tested.

9.2.11 A general examination of the electrical equipment in areas which may contain flammable gas or vapour and/or combustible dust is to be made to ensure that the integrity of the safe type electrical equipment has not been impaired owing to corrosion, missing bolts, etc., and that there is not an excessive build-up of dust on or in dust-protected electrical equipment. Cable runs are to be examined for sheath and armouring defects, where practicable, and to ensure that the means of supporting the cables are in good order. Tests are to be carried out to demonstrate the effectiveness of bonding straps for the control of static electricity. Alarms and interlocks associated with pressurised equipment or spaces are to be tested for correct operation. Particular attention should be given to cable runs in way of articulated joints and breaks in process deck boundaries.

9.2.12 Shipboard Automatic and Remote-Control Systems. In addition to the requirements of Annual Surveys, the following parts are to be examined:

(a) Control Actuators: All mechanical, hydraulic, and pneumatic control actuators and their power systems are to be examined and tested as considered necessary by the Surveyor.
(b) Electrical equipment: The insulation resistance of windings of electrical control motors or actuators is to be measured, with all circuits of different voltages above ground being tested separately to the Surveyor's satisfaction.
(c) Unattended Plants: Control systems for unattended machinery spaces are to be subjected to dock trials at reduced power on the propulsion engine to ensure the proper performance of all automatic functions, alarms and safety systems.

9.3 Docking Surveys and In-water Surveys

9.3.1 For production and oil storage units five years old and over, 9.2.11 is to be complied with. In addition, an electrical insulation resistance test of the circuits terminating in, or passing through, the dangerous areas is to be carried out.

■ *Section 10* Boilers

10.1 Frequency of surveys

10.1.1 All boilers, economisers, steam receivers, steam heated steam generators, thermal oil and hot water units intended for essential services, together with boilers used exclusively for non-essential services having a working pressure exceeding 3,5 bar and a heating surface exceeding 4,5 m^2 are to be surveyed internally. There is to be a minimum of two internal examinations during each five-year Special Survey cycle. The interval between any two such examinations is not to exceed 36 months. A general external examination is to be carried out at the time of the Annual Survey.

10.1.2 Consideration may be given in exceptional circumstances to an extension of the internal examination of the boiler, not exceeding three months beyond the due date. The extension may be granted after the following is satisfactorily carried out:

(a) External examination of the boiler.
(b) Examination and operational test of the boiler safety valve relieving gear (easing gear).
(c) Operational tests of the boiler protective devices.
(d) Review of the following records since the previous Boiler Survey:
    - Operation.
    - Maintenance.
    - Repair history.
    - Feedwater chemistry.

In this context, 'exceptional circumstances' means unavailability of repair facilities, essential materials, equipment or spare parts, or delays incurred by action taken to avoid severe weather conditions.

10.1.3 An external survey of boilers, including tests of safety and protective devices, and tests of safety valves using their relieving gear, is to be carried out annually within the range dates of the Annual Survey of the unit. For exhaust gas heated economisers, the safety valves are to be tested by the Chief Engineer at sea within the range dates of the Annual Survey. This test is to be recorded in the Log Book and reviewed by the attending Surveyor prior to crediting the Annual Survey.

10.2 Scope of surveys

10.2.1 At the surveys described in 10.1, the boilers, superheaters, economisers and air heaters are to be examined internally on the water-steam side and the fire side. Where considered necessary, the pressure parts are to be tested by hydraulic pressure and the thicknesses of plates and tubes and sizes of stays are to be ascertained to determine a safe working pressure. The safety valves and principal mountings on boilers, superheaters and economisers are to be examined and opened up as necessary by the Surveyor. The adjustment of safety valves is to be verified during each boiler internal survey. Boiler safety valves and their relieving gear are to be examined and tested to verify their satisfactory operation. Safety valves are to be set under steam to a pressure not greater than the approved design pressures of the respective parts. As a working tolerance, the setting is acceptable, provided that the valves lift at not more than 103 per cent of the approved design pressure. However, for exhaust gas heated economisers, if steam cannot be raised in port, the safety valves may be set by the Chief Engineer at sea, and the results recorded in the Log Book and reviewed by the attending Surveyor. The following records since the previous Boiler Survey are to be reviewed as part of the survey:

- Operation.
- Maintenance.
- Repair history.
- Feedwater chemistry.

The remaining mountings are to be examined externally and, if considered necessary by the Surveyor, are to be opened up for internal examination. Collision chocks, rolling stays and boiler stools are to be examined and maintained in an efficient condition.

10.2.2 In addition to the requirements of 10.2.1, in exhaust gas heated economisers of the shell type, all accessible welded joints are to be subjected to a visual examination in order to identify any evidence of cracking. Non-destructive testing may be required for this purpose and may be requested by the Surveyor.

10.2.3 In fired boilers employing forced circulation, the pumps used for this service are to be opened and examined at each Boiler Survey.

10.2.4 The oil fuel burning system is to be examined under working conditions and a general examination made of fuel tank valves, pipes, deck control gear and oil discharge pipes between pumps and burners.

10.2.5 At each survey of a cylindrical boiler which is fitted with smoke tube superheaters, the saturated steam pipes are to be examined as detailed in Section 11.

10.2.6 At the annual general examination referred to in 10.1.1, the requirements of 2.3.8 and 2.3.9 are to be complied with.

■ *Section 11* Steam pipes

11.1 Frequency of surveys

11.1.1 Saturated steam pipes, and superheated steam pipes where the temperature of the steam at the superheater outlet is not over 450°C, are to be surveyed 10 years from the date of build (or installation) and thereafter at five-yearly intervals.

11.1.2 Superheated steam pipes where the temperature of the steam at the superheater outlet is over 450°C are to be surveyed five years from the date of build (or installation) and thereafter at five-yearly intervals.

11.1.3 At 10 years from the date of build (or installation) and thereafter at five-yearly intervals, all copper or copper alloy steam pipes over 76 mm external diameter supplying steam for essential services at sea are to be hydraulically tested to twice the working pressure.

11.2 Scope of surveys

11.2.1 At each survey, a selected number of main steam pipes, also of auxiliary steam pipes, which:

(a) are over 76 mm external diameter;

(b) supply steam for essential services at sea; and

(c) have bolted joints,

are to be removed for internal examination and are to be hydraulically tested to 1,5 times the working pressure. If these selected pipes are found satisfactory in all respects, the remainder need not be tested. So far as is practicable, the pipes are to be selected for examination and hydraulic test in rotation so that in the course of surveys all sections of the pipeline will be tested.

11.2.2 Where main and/or auxiliary steam pipes of the category described in 11.2.1(a) and (b) have welded joints between the lengths of pipe and/or between pipes and valves, the lagging in way of the welds is to be removed, and the welds examined and, if considered necessary by the Surveyor, crack-detected. Pipe ranges having welded joints are to be hydraulically tested to 1,5 times the working pressure. Where lengths having ordinary bolted joints are fitted in such pipe ranges and can be readily disconnected, they are to be removed for internal examination and hydraulically tested to 1,5 times the working pressure.

11.2.3 Where, on cylindrical boilers having smoke tube superheaters, the saturated steam pipes adjoining the saturated steam headers are situated partly in the boiler smoke boxes, all such pipes adjoining and cross-connecting these headers in the smoke boxes are, at the surveys required by 11.1, to be included in the pipes selected for examination and testing, as defined in 11.2.1. Where the saturated steam pipes inside the smoke boxes consist of steel castings of substantial construction, these requirements need only be applied to a sample casting. Where steel castings are not fitted, the Surveyor is to be satisfied of the condition of the ends of the saturated steam pipes in the smoke boxes at each Boiler Survey and, if the Surveyor considers it necessary, a sample pipe is to be removed for examination.

11.2.4 At the surveys specified in 11.1.3, any of the copper or copper alloy pipes, such as those having expansion or other bends, which may be subject to bending and/or vibration, also closing lengths adjacent to steam driven machinery, are to be annealed before being tested.

11.2.5 Where it is inconvenient for the Owner to fulfil all the requirements of a Steam Pipe Survey at its due date, the Classification Committee will be prepared to consider postponement of the survey, either wholly or in part.

■ *Section 12* Screwshafts, tube shafts and propellers

12.1 Frequency of surveys

12.1.1 Shafts with keyed propeller attachments and fitted with continuous liners or approved oil glands, or made of approved corrosion resistant materials, are to be surveyed at intervals of five years when the keyway complies fully with the present Rules.

12.1.2 Shafts having keyless type propeller attachments are to be surveyed at intervals of five years, provided they are fitted with approved oil glands or are made of approved corrosion resistant materials.

12.1.3 Shafts having solid coupling flanges at the after end are to be surveyed at intervals of five years, provided they are fitted with approved oil glands or are made of approved corrosion resistant materials.

12.1.4 All other shafts not covered by 12.1.1 to 12.1.3 are to be surveyed at intervals of 2½ years.

12.1.5 Controllable pitch propellers for main propulsion purposes are to be surveyed at the same intervals as the screwshaft.

12.1.6 Directional propeller and podded propulsion units for main propulsion purposes are to be surveyed at intervals not exceeding five years.

12.1.7 Water jet units for main propulsion purposes are to be surveyed at intervals not exceeding five years, provided the impeller shafts are made of approved corrosion resistant material or have approved equivalent arrangements.

12.1.8 Dynamic positioning and/or thruster-assisted mooring and athwartship thrust propellers and shaftings are to be surveyed at intervals not exceeding five years.

12.2 Normal surveys

12.2.1 For self-propelled disconnectable units, screwshaft surveys held afloat at five-yearly intervals are to comply with the following:

(a) Measurement of bearing weardown.

(b) Verification of tightness of oil glands.

(c) Examination of propeller and fastenings.

(d) Verification on board of documentation of stern tube lubricating oil analysis carried out at regular intervals not exceeding six months. Each analysis, to be carried out on oil samples taken under service conditions and representative of oil within the stern tube, is to include the following minimum parameters:

  (i) Water content.

  (ii) Chloride content.

  (iii) Bearing material and metal particle content.

  (iv) Oil ageing (resistance to oxidation).

(e) Verification of records of oil consumption and bearing temperatures.

12.2.2 Directional propeller and podded propulsion units are to be dismantled for examination of the propellers, shafts, gearing and control gear.

12.2.3 Dynamic positioning and/or thruster-assisted mooring and athwartship thrust propellers are to be generally examined so far as is possible and tested under working conditions afloat for satisfactory operation.

12.2.4 Podded propulsion unit screwshaft roller bearings are to be renewed when the calculated life at the maximum continuous rating no longer exceeds the survey interval. *See* Pt 5, Ch 9,6.3.8.

12.3 Complete surveys

12.3.1 If a self-propelled unit enters dry dock any time after five years from the previous dry-docking, date of build or date of commissioning, as applicable, a complete screwshaft survey is to be held.

12.3.2 All screwshafts are to be withdrawn for examination by LR's Surveyors. The after end of the cylindrical part of the shaft and forward one third of the shaft cone, or fillet of the flange, is to be examined by a magnetic particle crack detection method. In the case of a keyed propeller attachment, at least the forward one third of the shaft cone is to be examined with the key removed. Weardown is to be measured and the sterntube bearings, oil glands, propellers and fastenings are to be examined. Controllable pitch propellers, where fitted, are to be opened up and the working parts examined, together with the control gear.

12.3.3 Directional propeller and azimuth thruster units are to be dismantled for examination of the propellers, shafts, gearing and control gear.

12.3.4 Water jet units are to be dismantled for examination of the impeller, casing, shaft, shaft seal, shaft bearing, inlet and outlets channels, steering nozzle, reversing arrangements, and control gear.

12.3.5 Dynamic positioning and/or thruster-assisted mooring and athwartship thrust propellers are to be generally examined so far as is possible and tested under working conditions afloat for satisfactory operation.

12.3.6 Podded propulsion unit screwshaft roller bearings are to be renewed when the calculated life at the maximum continuous rating no longer exceeds the survey interval. *See* Pt 5, Ch 9,6.3.8.

12.4 Screwshaft Condition Monitoring (SCM)

12.4.1 Where oil lubricated shafts with approved oil glands are fitted, and the Owner has complied with the following requirements, the ShipRight descriptive note **SCM** (Screwshaft Condition Monitoring) may be entered on the *ClassDirect Live* website:

(a) Lubricating oil analysis is to be carried out regularly at intervals not exceeding six months. The lubricating oil analysis documentation is to be available on board. Each analysis is to include the following minimum parameters:
  (i) Water content;
  (ii) Chloride content;
  (iii) Bearing material and metal particles content;
  (iv) Oil ageing (resistance to oxidation).
(b) Oil samples are to be taken under service conditions and are to be representative of the oil within the sterntube.
(c) Oil consumption is to be recorded.
(d) Bearing temperatures are to be recorded (two temperature sensors or other approved arrangements are to be provided).
(e) Facilities are to be provided for measurement of bearing weardown.
(f) Oil glands are to be capable of being replaced without withdrawal of the screwshaft.

12.4.2 For maintenance of the descriptive note **SCM**, the records of analyses, consumption and temperatures, together with weardown readings, are to be retained on board and audited annually.

12.4.3 Where the requirements for the descriptive note **SCM** have been complied with, the screwshaft need not be withdrawn at surveys as required by 12.3.2, provided all condition monitoring data is found to be within permissible limits and all exposed areas of the shaft are examined by a magnetic particle crack detection method. The remaining requirements of 12.3.2 are to be complied with. Where the Surveyor considers that the data presented is not entirely to his satisfaction, the shaft will be required to be withdrawn in accordance with 12.3.2.

12.5 Modified Survey

12.5.1 A Modified Survey may be accepted at alternate five-yearly surveys for shafts described in 12.1.1, provided that they are fitted with oil lubricated bearings and approved oil glands, and also for those in 12.1.2 and 12.1.3.

12.5.2 The Modified Survey is to consist of the partial withdrawal of the shaft, sufficient to ascertain the condition of the stern bearing and shaft in way. For keyless propellers or shafts with a solid flange connection to the propeller, a visual examination to confirm the good condition of the sealing arrangements is to be made. The oil glands are to be capable of being replaced without removal of the propeller. The forward bearing and all accessible parts, including the propeller connection to the shaft, are to be examined as far as possible. Wear down is to be measured and found satisfactory. Where a controllable pitch propeller is fitted, at least one of the blades is to be dismantled complete for examination of the working parts and the control gear.

12.5.3 For keyed propellers, the after end of the cylindrical part of the shaft and forward one-third of the shaft cone is to be examined by a magnetic particle crack detection method, for which dismantling of the propeller and removal of the key will be required.

12.6 Special cases

12.6.1 The Committee will be prepared to give consideration to the circumstances of any special case upon application by the Owner.

■ *Section 13*
Drilling plant facility

13.1 Frequency of surveys

13.1.1 Drilling units having a **DRILL** notation in accordance with Pt 3, Ch 7 are to be surveyed annually in accordance with the requirements of 2.7. A Special Survey in accordance with the requirements of 13.2 is to be held at intervals not exceeding five years.

13.2 Scope of surveys

13.2.1 At each Special Survey, the Surveyor is to examine and test as necessary the following components of the drilling plant facility:

- Blow out preventer hoisting and handling equipment.
- Blow out preventer, diverter and their controls.
- Bulk storage.
- Choke manifold and associated valves.
- Drilling fluids circulation and cementing equipment.
- Drilling derrick hoisting, rotation and pipe handling equipment.
- Heave compensation equipment.
- Miscellaneous drilling equipment and equipment considered as part of the drilling installation.
- Well testing equipment.

13.2.2 Pressure vessels forming part of the drilling plant facility are to be examined in accordance with the requirements of Section 17, *see also* 2.5 and 2.7.

13.2.3 Piping systems for mud, cement and other systems subject to considerable erosion are to be examined for leaks and corrosion.

13.2.4 Safety and communication systems and hazardous areas are to be examined in accordance with Section 16.

■ *Section 14*
Process plant facility

14.1 Frequency of surveys

14.1.1 Production and oil storage units having a **PPF** notation in accordance with Pt 3, Ch 8 are to be surveyed annually in accordance with the requirements of 2.5 and 2.7. A Special Survey in accordance with the requirements of 14.2 is to be held at intervals not exceeding five years.

14.2 Scope of surveys

14.2.1 At each Special Survey, the Surveyor is to examine and test as necessary the following components of the process plant facility:

- Major equipment of the production and process plant.
- Oil or gas processing system.
- Production plant safety systems.
- Production plant utility systems.
- Relief and flare system.
- Well control system.

14.2.2 Pressure vessels forming part of the process plant facility are to be examined in accordance with the requirements of Section 17, *see also* 2.5 and 2.7.

14.2.3 Piping systems and valves are to be examined for leaks and corrosion.

14.2.4 Safety and communication systems and hazardous areas are to be examined in accordance with Section 16.

■ *Section 15*
Riser systems

15.1 Surveys – General

15.1.1 For units having a **PRS** notation in accordance with Pt 3, Ch 12, Riser Systems are to be surveyed as per a planned survey schedule agreed between the Owners and LR. This schedule should cover the extent, level and method of systematic examination of critical components of the system.

15.1.2 Extent and frequency of thickness measurements of components and areas where deterioration may be expected due to corrosion are to be included in the above schedule.

15.1.3 An agreed schedule for periodic surveys should be capable of determining condition of riser pipe structure and associated critical components, such as any cladding, bend stiffeners, end connectors, subsea buoyant supporting vessels, subsea valves, anti-corrosive coatings, etc.

15.1.4 This schedule should also include examination and testing of the riser system under working conditions at each Annual Survey.

15.1.5 Emergency shut-down systems with associated communication system, telemetry or instrumentation, pressure relief systems, systems for leak detection and protection against pressure surges are to be tested at each Annual Survey as per agreed procedures.

■ *Section 16* Safety and communication systems and hazardous areas

16.1 Frequency of surveys

16.1.1 Safety and communication systems and hazardous areas are to be surveyed annually in accordance with the requirements of 2.4. A Special Survey of safety and communication systems and hazardous areas in accordance with the requirements of 16.2 is to be held at intervals not exceeding five years.

16.2 Scope of surveys

16.2.1 The Surveyor is to examine and be satisfied as to the efficient condition of the following systems as required by Part 7:

(a) Fire and gas alarm indication and control systems.
(b) Systems for broadcasting safety information.
(c) Protection system against gas ingress into safe areas.
(d) Protection system against gas escape in enclosed and semi-enclosed hazardous areas.
(e) Emergency shut-down (ESD) systems.
(f) Protection system against flooding, including:
  (i) Water detection alarm systems for watertight bracings, columns, pontoons, footings, void watertight spaces and chain lockers.
  (ii) Bilge level detection and alarm systems on column-stabilised units and in machinery spaces on surface type units.
  (iii) Remote operation and indication of watertight doors and hatch covers and other closing appliances.
(g) Fire detection and extinguishing apparatus.

16.2.2 Satisfactory operation of automatic shut-down devices and alarms is to be verified.

16.2.3 Enclosed hazardous areas such as those containing open active mud tanks, shale shakers, degassers and desanders are to be examined and doors and closures in boundary bulkheads verified as effective. Ventilating systems including duct work, fans, intake and exhaust locations for enclosed restricted areas are to be examined, tested and proven satisfactory. Ventilating-air alarm systems are to be proven satisfactory. In hazardous areas electric lighting, electrical fixtures, and instrumentation are to be examined, proven satisfactory and verified as explosion-proof or intrinsically safe. A complete survey of electrical installations is to be carried out in accordance with Section 9. Electrical motors are to be examined, including closed-loop ventilating systems for large d.c. motors. Automatic power disconnect to motors in case of loss of ventilating air is to be proved satisfactory.

16.2.4 Piping systems for process plant and other systems in hazardous areas are to be checked for leaks, corrosion, and the safe operation of valves. Piping systems are to be tested when required by the Surveyor.

16.2.5 Pressure vessels and safety devices are to be subject to surveys in accordance with the requirements of Section 17.

■ *Section 17* Pressure vessels for process and drilling plant

17.1 Frequency of surveys

17.1.1 All pressure vessels are to be examined at the first Annual Survey after commissioning and subsequently at each Special Survey, *see* 2.3.8 and 2.3.9.

17.2 Scope of surveys

17.2.1 At the surveys described in 17.1, all pressure vessels are to be examined internally and externally. Principal mountings, supports and attachments to pressure vessels are to be examined, *see also* 17.2.4.

17.2.2 Where pressure vessels are so constructed that internal inspection is prevented by normal means, agreed tests are to be carried out to the satisfaction of the Surveyor.

17.2.3 Where, due to operational requirements, it is not possible to present all pressure vessels for inspection at the first Annual Survey, a sufficient number of pressure vessels from each system is to be examined, as agreed with the Surveyor, in order to establish the extent of corrosion and general condition of the system. The Owner's proposals for the inspection of the remaining pressure vessels are to be included in the Owner's planned maintenance and inspection procedure, as required by 1.6.

17.2.4 Selected pressure safety valves are to be bench tested in accordance with the requirements of 2.5 and 2.7. The Surveyor is to confirm that all pressure safety valves forming part of the process and drilling plant facility are examined and bench tested within each special survey cycle.

■ *Section 18* Inert gas systems

18.1 Frequency of surveys

18.1.1 Inert gas systems installed on board units intended for the storage of oil in bulk storage tanks are to be surveyed annually in accordance with the requirements of 2.6. A Special Survey of the inert gas system, in accordance with the requirements of 18.2, is to be held at intervals not exceeding five years.

18.2 Scope of surveys

18.2.1 At each Special Survey of the inert gas system, the inert gas generator, scrubber and blower are to be opened out as considered necessary and examined. Gas distribution lines and shut-off valves, including soot blower interlocking devices, as well as interlocking features and positive isolation for tank isolation are to be examined as considered necessary. The deck seal and non-return valve are to be examined. Cooling water systems including the effluent piping and overboard discharge from the scrubbers are to be examined. All automatic shut-down devices and alarms are to be tested. The complete installation is to be tested under working conditions on completion of survey.

18.2.2 When, at the request of an Owner, it has been agreed by the Classification Committee that the Complete Survey of the inert gas systems may be carried out on the Continuous Survey basis, the various items of machinery are to be opened for survey in rotation, so far as practicable, to ensure that the interval between consecutive examinations of each item will not exceed five years. In general, approximately one fifth of the machinery is to be examined each year.

18.2.3 If any examination during Continuous Survey reveals defects, further parts are to be opened up and examined as considered necessary by the Surveyor, and the defects are to be made good to his satisfaction.

■ *Section 19* Classification of units not built under survey

19.1 General

19.1.1 When classification is desired for a unit not built under the supervision of LR's Surveyors, application should be made to the Committee in writing.

19.1.2 Periodical Surveys of such units, when classed, are subsequently to be held, as in the case of units built under survey.

19.1.3 Where classification is desired for a unit which is classed by another recognised Society, special consideration will be given to the scope of the survey.

19.2 Hull and equipment

19.2.1 Plans showing the main scantlings and arrangements of the actual unit, together with any proposed alterations, are to be submitted for approval. These should comprise plans of the main hull/structure, including midship section, longitudinal and transverse sections, columns, decks, pontoons, bracings, legs and footings and such other plans as may be requested. If the class notation **DRILL** or **PPF** is to be assigned in accordance with Pt 3, Ch 7 or Ch 8 respectively, plans and documentation covering the major structures of the plant are to be submitted as may be requested.

19.2.2 If plans cannot be obtained or prepared by the Owner, facilities are to be given for LR's Surveyor to obtain the necessary information from the unit. The unit's Operations Manual is also to be submitted, *see* Pt 3, Ch 1,3.

19.2.3 Particulars of the process of manufacture, material grades and the testing of the material of construction are to be supplied.

19.2.4 In all cases, the full requirements of Section 5 are to be carried out as applicable. Units of recent construction will receive special consideration.

19.2.5 During the survey, the Surveyors are to satisfy themselves regarding the workmanship and verify the approved scantlings and arrangements. For this purpose, and in order to ascertain the amount of any deterioration, parts of the structure will require to be gauged as necessary. Full particulars of the anchors, chain cables and equipment are to be submitted. Loading instruments, where required, are to be in accordance with the Rules, *see* Ch 2,1.1 as applicable.

19.2.6 Safety and communication systems are to be verified in accordance with 19.3.14, *see also* Ch 3,1.1.

19.2.7 When the full survey requirements indicated in 19.2.4 and 19.2.5 cannot be completed at one time, the Classification Committee may consider granting an interim record for a limited period. The conditions regarding the completion of the survey will depend on the merits of each particular case, which should be submitted for consideration.

19.3 Machinery

19.3.1 To facilitate the survey, plans of the following items (plans of piping are to be diagrammatic), together with the particulars of the materials used in the construction of the boilers, air receivers and important forgings are to be supplied:

- General pumping arrangements, including air and sounding pipes (Builder's plan).
- Pumping arrangements at the forward and after ends of units with crude oil bulk storage tanks and drainage of cofferdams and pump-rooms.
- General arrangement of crude oil storage piping in tanks and on deck.
- Piping arrangements for bulk oil storage (F.P. 60°C or above, closed-cup test).
- Bilge, ballast and oil fuel pumping arrangements in the machinery space, including the capacities of the pumps on bilge service.
- Arrangement and dimensions of main steam pipes.
- Arrangement of oil fuel pipes and fittings at settling and service tanks.
- Arrangement of oil fuel and gas piping in connection with oil and gas burning installations.
- Oil fuel and bulk oil storage overflow systems, where these are fitted.
- Arrangement of boiler feed systems.
- Oil fuel settling, service and other oil fuel tanks not forming part of the unit's structure.
- Boilers, superheaters and economisers.
- Air receivers.
- Crank, thrust, intermediate and screw shafting.
- Clutch and reversing gear with methods of control.
- Reduction gearing.
- Propeller (including spare propeller if supplied).
- Azimuth thrusters.
- Electrical circuits.
- Hazardous areas.
- Arrangement of compressed air systems for main and auxiliary services.
- Arrangement of lubricating oil, other flammable liquids and cooling water systems for main and auxiliary services.
- General arrangement of crude oil storage tank vents. The plan is to indicate the type and position of the vent outlets from any superstructure, erection, air intake, etc. Ventilation arrangements of storage tanks and/or ballast pump-rooms and other enclosed spaces which contain crude oil handling equipment.
- Safety and communication systems, *see* Pt 7, Ch 1.
- Jacking arrangements on self-elevating units.

19.3.2 Plans additional to those detailed in 19.3.1 are not to be submitted unless the machinery is of a novel or special character affecting classification. If the class notation **DRILL** or **PPF** is to be assigned in accordance with Pt 3, Ch 7 or Ch 8 respectively, plans and documentation covering the plant are to be submitted as may be requested.

19.3.3 Where remote and/or automatic controls are fitted to propulsion machinery and essential auxiliaries, a description of the scheme is to be submitted.

19.3.4 For new units and units which have been in service less than two years, calculations of the torsional vibration characteristics of the propelling machinery are to be submitted for consideration, as required for ships constructed under Special Survey. For older units, the circumstances will be specially considered in relation to their service record and type of machinery installed. Where calculations are not submitted, the Classification Committee may require that the machinery certificate be endorsed to this effect. When desired by the Owner, the calculations and investigation of the torsional vibration characteristics of the machinery may be carried out by LR upon special request.

19.3.5 The main and auxiliary machinery, feed pipes, compressed air pipes and boilers are to be examined as required at Complete Surveys. Working pressures are to be determined from the actual scantlings in accordance with the Rules.

19.3.6 Pressure vessels for process and drilling plant are to be examined as required for Special Surveys in Section 17.

19.3.7 The screwshaft is to be drawn and examined.

19.3.8 The steam pipes are to be examined and tested as required by Section 11.

19.3.9 The bilge, ballast and oil fuel pumping arrangements are to be examined and amended, as necessary, to comply with the Rules.

19.3.10 Oil and gas burning installations are to be examined as required at Complete Surveys and found, or modified, to comply with the requirements of the Rules; they are also to be tested under working conditions.

19.3.11 The electrical equipment is to be examined as required at Complete Surveys in Section 9.

19.3.12 Where an inert gas system is fitted on units intended for the storage of oil in bulk having a flash point not exceeding 60°C, the requirements of Pt 5, Ch 15,7 apply.

19.3.13 The whole of the machinery, including essential controls, is to be tested under working conditions to the Surveyor's satisfaction.

19.3.14 Safety and communication systems and hazardous areas are to be examined as required at Special Surveys in Section 17. The requirements of Part 7 are to be complied with.

Section 20
Laid-up machinery

20.1 Survey requirements

20.1.1 Main and/or auxiliary propulsion, main and auxiliary steering gear and jack-up machinery not in use when the installation is operating at a fixed location may not be subject to periodic surveys as required by Sections 2 to 19. The machinery may be retained on board in laid-up status as per manufacturers' recommendations. However, all overdue surveys and reactivation requirements are to be dealt with prior to recommissioning. The reactivation requirements will be advised by LR on request.

20.1.2 If laid-up machinery is required to be used when the unit is disconnected from its moorings in an emergency, the periodic maintenance and operation schedules are to be in accordance with the manufacturers' recommendations and specially agreed to by LR.

Section 1
Conditions for verification

1.1 General requirements

1.1.1 It is the responsibility of Owners, Operators or Duty Holders to comply with all aspects of National Legislation applicable to units and installations engaged in petroleum activities in controlled waters.

1.1.2 When LR is requested by an Owner, Operator or Duty Holder to carry out verification in accordance with the Regulations of the coastal state authority, verification approval will be carried out in accordance with this Chapter.

1.1.3 Verification will be carried out to the specific provisions of the coastal state Regulations, as agreed with the Owner, Operator or Duty Holder, and appropriate to the proposed descriptive note and the type of unit and its function.

1.1.4 For the assignment of a National Authority descriptive note as defined in Ch 2,2.7, compliance with the coastal state Regulations will be considered in addition to the requirements of the Rules.

1.1.5 Verification will be based on LR's interpretation of the coastal state Regulations as applicable to the type of unit and its function. Where appropriate, the coastal state Regulations will take precedence over the Classification Rules if considered more stringent.

1.1.6 The verification approval will cover only the standards of design, construction, materials, workmanship, equipment, machinery, systems and installed plant as prescribed by the Regulations. Those aspects concerning operations, personnel equipment and the overall safety philosophy will be the responsibility of the Owner, Operator and/or Duty Holder.

1.1.7 LR can also advise Owners, Operators and/or Duty Holders on safety aspects and carry out risk analyses on their behalf, in order to provide the documentation required in the internal control system as stipulated by the coastal state.

1.1.8 Risk analyses will not be included in Classification but when the coastal state Regulations contain specific requirements relating to risk analyses, the results of the relevant risk analyses will be considered when carrying out verification approval for an appropriate National Authority descriptive note defined in Chapter 2.

1.2 Existing units

1.2.1 In the case of an existing classed mobile unit or installation which has been built in accordance with the legislation of a coastal state, other than that now required, LR will carry out a comparison with the coastal state Regulations as applicable. Deviations from the required coastal state Regulations which do not achieve an equivalent safety standard will be listed.

1.2.2 When an existing unit is converted or modified, any new modifications, technical equipment or system are to comply with the required coastal state Regulations, as applicable.

1.3 Recognised Codes and Standards

1.3.1 When the coastal state Regulations do not refer to specific Codes or Standards or define specific acceptance criteria, verification approval will be carried out in accordance with the class Rules or, where appropriate, in accordance with internationally recognised Codes and Standards. *See* Pt 3, Appendix A.

1.3.2 The class Rules and/or recognised Codes and Standards may also be used for verification approvals when they are considered to provide an equivalent standard to the coastal state Regulations or when additional requirements are considered necessary to meet LR's interpretation of the Regulations.

1.3.3 The mixing of different parts of Codes and Standards is to be avoided.

Section 2
Documentation

2.1 Certificates

2.1.1 When the requirements of the coastal state Regulations have been complied with to LR's satisfaction, certificates and a design appraisal declaration will be issued.

2.1.2 In general, if there are non-compliances with any parts of the coastal state Regulations, the non-compliance items will be required to be cleared to LR's satisfaction before the issue of Interim Certificates of Classification by the Surveyors. Any deviations from the coastal state Regulations will be listed in the design appraisal declaration.

2.1.3 In the case of an existing unit, the requirements of 1.2 are to be complied with.

2.1.4 If there are any serious non-compliances with the coastal state Regulations which could have an effect on the overall safety of the vessel or installation, the National Authority descriptive note may be withheld at the discretion of the Committee.

■ *Section 3* Descriptive note

3.1 General

3.1.1 After verification approval has been carried out in accordance with 1.1.2 to LR's satisfaction, a National Authority descriptive note will be assigned by the Committee in accordance with Ch 2,2.7.

3.1.2 National Authority descriptive notes may be utilised by the Owner, Operator or Duty Holder as part of the documentation required in the internal control system as stipulated by the coastal state Regulations.

3.1.3 When a National Authority descriptive note has been assigned in accordance with Ch 2,2.7, an additional entry will be made on the ClassDirect Live website.

■ *Section 4* Survey requirements

4.1 General

4.1.1 New units, vessels and installations are to be built under LR's Special Survey and, during service, periodic surveys are to be carried out in accordance with Chapter 3.

4.1.2 When a National Authority descriptive note has been assigned in accordance with Ch 2,2.7, the condition of the unit, vessel or installation shall be documented by periodic surveys in accordance with the applicable coastal state Regulations.

4.1.3 A routine system for planning and implementation of periodic surveys for condition monitoring of the unit, vessel or installation in accordance with the applicable coastal state Regulations shall be proposed by the Owner, Operator and/or Duty Holder and be agreed with LR.

4.1.4 In general, condition monitoring surveys as required by the coastal state Regulations should be carried out at the same time as normal periodical class surveys in accordance with Chapter 3.

Rules for the Manufacture, Testing and Certification of Materials

July 2013

LIFE MATTERS

A guide to the Rules

and published requirements

Rules for the Manufacture, Testing and Certification of Materials

Introduction

The Rules are published as a complete set; individual Parts are, however, available on request. A comprehensive List of Contents is placed at the beginning of each Part.

Numbering and Cross-References

A decimal notation system has been adopted throughout. Five sets of digits cover the divisions, i.e. Part, Chapter, Section, sub-Section and paragraph. The textual cross-referencing within the text is as follows, although the right hand digits may be added or omitted depending on the degree of precision required:

(a) In same Chapter, e.g. *see* 2.1.3 (i.e. down to paragraph).

(b) In another set of Lloyd's Register Rules, e.g. *see* Pt 5, Ch 3,2.1 of the Rules and Regulations for the Classification of Ships.

The cross-referencing for Figures and Tables is as follows:

(a) In same Chapter, e.g. as shown in Fig. 2.3.5 (i.e. Chapter, Section and Figure Number).

(b) In another set of Lloyd's Register Rules, e.g. *see* Table 2.7.1 in Pt 3, Ch 2 of the Rules and Regulations for the Classification of Special Service Craft.

Rules updating

The Rules are generally published annually and changed through a system of Notices. Subscribers are forwarded copies of such Notices when the Rules change.

Current changes to Rules that appeared in Notices are shown with a black rule alongside the amended paragraph on the left hand side. A solid black rule indicates amendments and a dotted black rule indicates corrigenda.

July 2013

RULES FOR THE MANUFACTURE, TESTING AND CERTIFICATION OF MATERIALS

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■ *Section 1* Scope

1.1 General

1.1.1 Materials used for the construction, conversion, modification or repair of ships, other marine structures and associated machinery which are classed or are intended for classification by Lloyd's Register (hereinafter refered to as LR), are to be manufactured, tested and inspected in accordance with these Rules.

1.1.2 Wrought, cast and extruded materials are to comply with the requirements of Chapters 1 and 2, and the appropriate specific requirements of Chapters 3 to 9 of these Rules. Mooring and anchoring equipment is to comply with the requirements of Chapters 1 and 2, and the appropriate specific requirements of Chapter 10. Manufacturers of these materials must be approved by LR according to the requirements in Sections 2 or 3. Only those materials within a manufacturer's scope of approval may be used.

1.1.3 Welding consumables are to comply with the requirements of Chapter 11 of these Rules.

1.1.4 Where welding is used for the construction, conversion, modification or repair of ships, other marine structures and associated machinery which are classed or are intended for classification by LR, welding qualifications and tests shall be performed according to Chapter 12 of these Rules. All welding shall be performed according to Chapter 13 of these Rules.

1.1.5 Plastics materials are to comply with the requirements of Chapter 14 of these Rules.

1.1.6 The materials and components which are to comply with these requirements for the purposes of classification are defined in the relevant Rules dealing with design and construction.

■ *Section 2* Approval and survey requirements

2.1 Approval and survey requirements – General

2.1.1 Marine materials manufactured in accordance with Chapters 3 to 10 of these Rules are to be made at works which have been approved by LR for the type and grade of product being supplied.

2.1.2 Materials manufactured in accordance with Chapters 3 to 10 of these Rules are to be manufactured, tested and inspected under Survey according to the requirements of one of the following two schemes:
(a) The Materials Survey Scheme, *see* 2.3.
(b) The Materials Quality Scheme, *see* 2.4.

2.1.3 For the purposes of survey, LR Surveyors are to be allowed access to all relevant parts of the works, and are to be provided with the necessary facilities and information to enable them to verify that the manufacture is being carried out in accordance with the approved procedures. Facilities are also to be provided for the selection of test material, the witnessing of mechanical tests and the examination of materials, as required by these Rules.

2.1.4 Where a production process, testing or examination of materials is sub-contracted, this must be with the approval of LR. Surveyors are to be allowed access to the sub-contractor's premises in order to conduct Surveys according to the requirements of these Rules.

2.1.5 Products manufactured in accordance with Chapters 11 and 14 are to be approved in accordance with the requirements therein. For these materials, approval is given for a specific product on a type approval basis, rather than the approved manufacturer/survey arrangements applied to materials covered by Chapters 3 to 10.

2.2 LR Approval – General

2.2.1 Unless specifically stated in other Chapters of these Rules, all LR approvals apply to materials used in applications intended for marine service, as described in 1.1.

2.2.2 The procedures for application for approval of manufacturers and products, the details of the information to be supplied by the manufacturer, and the test programme to be conducted on the products are given in the appropriate book of LR's *Materials and Qualification Procedures for Ships* (MQPS). This is published in the CD Live section of LR's web site at http://www.lr.org.

2.2.3 LR publishes lists of approved manufacturers and approved products. The lists are published in the CD Live section of LR's website, http://www.lr.org.
The lists are as follows:

- *List of Approved Manufacturers of Materials*.
- *Approved Welding Consumables for Use in Ship Construction*.
- *Lists of Paints, Resins, Reinforcements and Associated Materials*.
- *Lists of Approved Anchors*.

2.2.4 For initial LR approval as an Approved Manufacturer for a particular material, the manufacturer is required to demonstrate to the satisfaction of LR, that the necessary manufacturing and testing facilities are available, and are supervised by suitably qualified personnel. A specified programme of tests is to be carried out under the supervision of LR Surveyors, and the results are to be to the satisfaction of LR.

2.2.5 If the results of the initial assessment of the manufacturer, and the test programme are considered satisfactory, the manufacturer will be added to the list of approved manufacturers of materials, and a certificate of approval will be issued to the manufacturer by LR, showing the scope of materials and grades covered by the approval. Initial approval will generally be under the Materials Survey Scheme, *see* 2.3.

2.2.6 Approved manufacturers who meet the entry requirements, may apply for approval under the Materials Quality Scheme, *see* 2.4.

2.2.7 When a manufacturer has more than one works, the manufacturer's approval shall only be valid for the works where the test programme was conducted.

2.2.8 It is the manufacturer's responsibility to advise LR of all changes to the manufacturing process parameters that may affect the application of the material, prior to the adoption of the changes in production. Additional approval tests may be required to maintain the approval.

2.2.9 Maintenance of approval is dependent on the manufacturer continuing to meet the requirements of the applicable sections of these Rules.

2.2.10 Where it is considered that an approved manufacturer is not maintaining its responsibilities to comply with these Rules, the approval may be suspended by LR until such time that agreed corrective and preventive actions are considered to have been satisfactorily carried out. If considered necessary, LR may require that the normal level of testing and inspection is increased.

2.2.11 In all instances, LR will reduce the scope of, or withdraw approval from, a manufacturer where it becomes apparent that the manufacturer is unable to maintain compliance with these Rules, or the scope of approval.

2.2.12 Where a manufacturer disagrees with any decisions made with regard to LR approval, they may appeal in writing to LR.

2.2.13 Any documents, data or other information received as part of the approval process, will be treated as strictly confidential, and will not be disclosed to any third party, without the manufacturer's prior written consent.

2.2.14 The approved works will be subject to a periodic inspection of all relevant parts of the works, at intervals not exceeding three years. The procedure for this periodic inspection is given in Book B of LR's *Materials and Qualification Procedures for Ships* (MQPS). This periodic inspection is in addition to the regular visits made according to 2.3.7.

2.3 Materials Survey Scheme

2.3.1 Materials according to Chapters 3 to 10 of these Rules and produced under the Materials Survey Scheme will be subject to Direct Survey by an LR Surveyor. The scheme requires the Surveyor to survey and certify all materials according to the requirements of these Rules.

2.3.2 Approved manufacturers are to request a survey of the material by an LR Surveyor, when required. Manufacturers must provide the Surveyor with details of the order, specification and any special conditions additional to the requirements of these Rules.

2.3.3 All mechanical tests required by these Rules are to be witnessed. The Surveyor may allow part of this task to be carried out by a member of the works staff by prior written agreement.

2.3.4 Before final acceptance, all materials are to be submitted to the specified tests and examinations under conditions acceptable to the Surveyor. The results are to comply with the Rules, and all materials are to be to the satisfaction of the Surveyor.

2.3.5 The specified tests and examinations are to be carried out prior to the despatch of finished materials from the manufacturer's works. Where materials are supplied in the rough or unfinished condition, as many as possible of the specified tests are to be carried out by the manufacturer, and any tests or examinations that are not completed are to be carried out under survey at a subsequent stage of manufacture.

2.3.6 In the event of any material proving unsatisfactory during subsequent working, machining or fabrication, such material is to be rejected, notwithstanding any previous certification.

2.3.7 In addition to witnessing test results, the Surveyor is responsible for ensuring that the manufacturing process, inspection, testing, identification and certification are properly conducted. As part of the Materials Survey Scheme, regular visits will be made to all relevant parts of the works to check for compliance against the requirements of these Rules, and to ensure that the manufacturer is maintaining the capability to consistently produce approved materials.

2.3.8 The Surveyor, when satisfied that the material fully meets the requirements of these Rules, will certify the material in accordance with Section 3 and the appropriate Chapter of these Rules.

2.4 Materials Quality Scheme

2.4.1 The manufacturer may apply to be approved under the Materials Quality Scheme, where the following requirements are met:

(a) The manufacturer has been approved by LR for a minimum of three years and continues to maintain their LR works approval according to 2.2.14; and
(b) The manufacturer has a quality management system, which has been certified as meeting the requirements of ISO 9001 by a certification body recognised by LR, which is one accredited by a member of the International Accreditation Forum; and
(c) The manufacturer has a satisfactory history of quality performance in the manufacture and supply of LR approved materials.

2.4.2 Special consideration may be given to manufacturers who have not been approved under the Materials Survey Scheme, and may be considered onto the Materials Quality Scheme providing:

(a) They have a quality management system, which has been certified as meeting the requirements of ISO 9001 by a certification body recognised by LR, which is one accredited by a member of the International Accreditation Forum.
(b) They can demonstrate a history of satisfactory supply of materials, which LR deems to be equivalent to those for which approval under the Materials Quality Scheme is requested.

In this case, the initial assessment of the manufacturer will include the product testing regime, as required for initial approval under the Materials Survey Scheme, *see* 2.2.4.

2.4.3 The Scheme is based on a Scheme Certification Schedule, made between LR and each individual manufacturer. The schedule will stipulate:

(a) The scope of approved products covered by the approval.
(b) The process route applied by the manufacturer for each approved product.
(c) The arrangements for LR scheme, audits, including scope, frequency, schedule, etc.
(d) Agreed procedures for certification of approved materials.
(e) Information to be supplied periodically to LR by the manufacturer.
(f) Procedures for the use of the scheme mark.

2.4.4 The contents of the Scheme Certification Schedule are to remain confidential between LR and the manufacturer.

2.4.5 The Materials Quality Scheme is based on a technical audit approach, and is designed to complement the quality management systems audits performed to ISO 9001. The role of the Surveyor in scheme audits is to:

(a) Verify that the quality management system is being maintained and audited to the requirements of ISO 9001.
(b) Verify that the requirements of these Rules are being implemented.
(c) Verify that the requirements of this Scheme are being implemented.
(d) Perform Scheme audits, which focus on the technical aspects of the product realisation process, particularly with regard to Rule requirements.
(e) Perform witness testing as required.
(f) Verify the data supplied to LR periodically by the manufacturer, as part of the Scheme requirements.

2.4.6 The Materials Quality Scheme may be applied to any approved manufacturer who meets the eligibility requirements, and who applies to be approved under the scheme. If approved under the scheme, the manufacturer's name will appear on the List of Approved Manufacturers published by LR, with an indication that they are approved under this scheme.

2.4.7 The scheme is available to manufacturers producing approved materials according to Chapters 3 to 10 of these Rules.

2.4.8 The procedures for application for approval for the Materials Quality Scheme are given in Book M of LR's *Materials and Qualification Procedures for Ships* (MQPS).

2.4.9 Where LR is satisfied that the manufacturer meets all of the requirements of the Scheme, and that it is appropriate for the products being manufactured, a Scheme Certification Schedule will be issued, which must be signed by an authorised representative of the manufacturer.

2.4.10 Once the Scheme Certification Schedule has been signed by both parties, LR will issue the manufacturer with a certificate of approval according to the Materials Quality Scheme.

2.4.11 Maintenance of approval will be according to the Scheme Certification Schedule, agreed between LR and the manufacturer, and these Rules.

2.4.12 It is the responsibility of the attending Surveyor, to perform regular Scheme audits at the manufacturer's works in accordance with the Scheme Certification Schedule, and the requirements of these Rules.

2.4.13 It is not the intention to repeat the audit according to ISO 9001, conducted by the recognised certification body. The Surveyor is, however, to be satisfied that these audits are being conducted effectively. Where appropriate, the Surveyor may conduct a partial audit to ISO 9001 to verify this.

2.4.14 Witness tests may be conducted as part of the Scheme audit. This will involve the selection of material, and the witness of sampling and testing according to the requirements of the appropriate chapter of these Rules. Such witness testing may be on LR grades, or materials which the Surveyor deems to be equivalent (for the purposes of audit testing only).

2.4.15 Once every three years, a full assessment of scheme compliance will be conducted by a Surveyor who is not the regular attending Surveyor. This assessment is in addition to the periodic inspection requirement made according to 2.2.14.

2.4.16 In the event of any change, which means that the manufacturer no longer meets the requirements for the Materials Quality Scheme (for example the loss of ISO 9001 approval), the Scheme certificate of approval will be revoked. The manufacturer will revert to the Materials Survey Scheme, and will be subject to survey according to that scheme.

■ *Section 3* Certification of materials

3.1 General

3.1.1 All materials subject to these Rules are to be supplied with appropriate certification, as required by the relevant requirements of these Rules. This will normally be a LR certificate or a manufacturer's certificate validated by LR, although a manufacturer's certificate may be accepted where allowed by the relevant requirements of these Rules.

3.1.2 Manufacturers approved under the Materials Quality Scheme are licensed to apply the scheme mark to manufacturer's certificates according to the requirements of the scheme, *see* 2.4.

3.1.3 The following certificate types are to be used, (a) and (b) for the Materials Survey Scheme, and (d) for the Materials Quality Scheme:

(a) **LR Certificate**
This type of certificate is issued by LR based on the results of testing and inspection being satisfactorily carried out in accordance with the requirements of these Rules.

(b) **Manufacturer's certificate validated by LR**
A manufacturer's certificate, validated by LR on the basis of inspection and testing carried out by the manufacturer and which is in accordance with the requirements of these Rules, may be accepted. In this case, the certificate will include the following statement:
"We hereby certify, that the material has been made by an approved process and satisfactorily tested in accordance with the Rules of Lloyd's Register."

(c) **Manufacturer's certificate**
This type of certificate is issued by the manufacturer, based on the results of testing and inspection being satisfactorily carried out in accordance with the requirements of these Rules, or the applicable National or International standard. The certificate is to be validated by the manufacturer's authorised representative, independent of the manufacturing department. The certificate will contain a declaration that the products are in compliance with the requirements of these Rules or the applicable National or International standard.

(d) **Manufacturer's certificate issued under the Materials Quality Scheme**
Where a manufacturer is approved according to the Materials Quality Scheme, they will issue manufacturer's certificates bearing the scheme mark. The certificates must also bear the following statement:
"This certificate is issued under the arrangements authorised by Lloyd's Register (operating group) in accordance with the requirements of the Materials Quality Scheme and certificate number MQS ……."

3.1.4 Where these Rules allow for the issue of a manufacturer's certificate for materials, either validated by an LR Surveyor, or bearing the Materials Quality Scheme mark, the manufacturer is to ensure that a copy of the certificate is supplied to LR.

3.2 Materials Survey Scheme

3.2.1 The requirements for certification of materials according to the Materials Survey Scheme, are established by the relevant requirements of these Rules.

3.2.2 The manufacturer is to supply the surveyor with any additional customer order requirements that are in addition to the requirements of these Rules, when the request for the issue or validation of the certificate is made.

3.3 Materials Quality Scheme

3.3.1 Part of the certification schedule, will include an agreement for the manufacturer, to apply the scheme mark to manufacturer's certificates, relating to approved products within the scope of approval of the manufacturer.

3.3.2 The use of the scheme mark is governed by the following:

(a) The use of the scheme mark is not transferable. It is only to be used in conjunction with the manufacturer and works name and location shown on the certificate of approval.
(b) The scheme mark must be applied to all manufacturers' certificates relating to approved materials produced under the Scheme.
(c) In no circumstances is the scheme mark to be applied to test certificates relating to non-approved products.
(d) The scheme mark is not to be used in any way which may imply approval for products which are not covered within the manufacturer's scope of approval.
(e) Where a manufacturer is removed or suspended from the scheme, use of the scheme mark must cease immediately.

3.3.3 The certificate as given in 3.1.3(d) is to be validated by an authorised representative of the manufacturer. The size and position of the scheme mark and statement on the manufacturer's certificate must be agreed by LR.

3.3.4 Where manufacturers are approved under this scheme, the manufacturer's certificate, issued according to these requirements, fully meets the materials certification requirements of these Rules.

3.4 Electronic certification

3.4.1 Where these Rules allow the issue of manufacturers' test certificates, under either the Materials Survey Scheme or the Materials Quality Scheme, these may be issued in electronic format provided that:

(a) All tests and inspections have been satisfactorily completed, according to the requirements of these Rules.

(b) Procedures are in place to ensure that electronic certificates are only issued, according to the requirements of these Rules.
(c) The certification system is subject to regular inspection by the attending Surveyor.
(d) A copy of the electronic certificate is supplied to LR. This copy will be deemed to be the original of the test certificate.

3.4.2 In addition to the requirements of 3.4.1, for items certified under the Materials Survey Scheme, the LR office stamp and Surveyor's name may be applied electronically. This is only allowed where the Surveyor has access to the results of the relevant tests and inspections, and is able to authorise by access to the electronic system, the application of the LR office stamp and Surveyor's name on the test certificate. The name of the authorising Surveyor is to be the name included on the certificate. The authorisation may be conducted electronically either at the manufacturers' works, or remotely by the Surveyor.

3.4.3 If the LR office stamp and name are being applied electronically according to 3.4.2, then the manufacturer is to ensure that the Surveyor is provided with all relevant information regarding the customer order, when the request for authorisation is made.

■ *Section 4* General requirements for manufacture

4.1 General

4.1.1 The following definitions are applicable to these Rules:

Item: A single forging, casting, plate, tube or other rolled product as delivered.
Piece: The rolled product from a single slab or billet or from a single ingot if this is rolled directly into plates, strip, sections or bars.
Batch: A number of similar items or pieces presented as a group for acceptance testing.
Wide flat: Flat product of a width over 150 mm, up to and including 1250 mm and thickness generally over 4 mm. Edges are square cut, i.e., hot rolled on the four sides. Supplied in lengths, not coils.
Plate/sheet: Flat rolled product whereby the edges are allowed to deform freely. Supplied flat and generally in square or rectangular shapes with a width of 600 mm or over, but other shapes may also apply.

4.1.2 Where a manufacturer purchases semi-finished products (e.g., slabs) for the purpose of re-processing (e.g., rolling), the manufacturer is to ensure that the materials are from an LR approved manufacturer, and manufactured within the scope of approval of that manufacturer. The aim of chemical analysis, dimensions, surface and internal quality checks are to be agreed between the manufacturer and purchaser. The semi-finished materials must be supplied with appropriate certification, according to these Rules.

4.1.3 It is the responsibility of the manufacturer, to ensure compliance with all relevant aspects of these Rules. All deviations are to be recorded as non-compliances, and brought to the attention of the Surveyor, along with corrective actions taken. Failure to do this is considered to render the material as not complying with these Rules.

4.1.4 The manufacturer is to maintain all test and inspection records required by these Rules for at least seven years. Records are to be made available to LR on request.

4.1.5 Where material is produced which does not meet all aspects of these Rules, the manufacturer may apply to LR for a concession to certify the material as approved. LR will consider each application on a case-by-case basis, although concession will only normally be granted in exceptional circumstances. If the concession is granted, a formal written numbered concession will be issued to the manufacturer. The concession number must be applied to the approval certificate, whether it is an LR certificate or a validated manufacturer's certificate.

4.2 Chemical composition

4.2.1 The ladle analysis used for certification purposes is to be determined after all alloying elements have been added and sufficient time allowed for such additions to equalise throughout the ladle.

4.2.2 The method of taking samples is to ensure that the reported analysis is representative of the cast. In addition, the manufacturer must determine and certify the chemical composition of every heat of material.

4.2.3 Where more than one sample is taken, the method of averaging for the final certificate result and the determination of acceptable variations in composition are to be agreed with the Surveyor.

4.2.4 The chemical composition of ladle samples is to be determined by the manufacturer in an adequately equipped and competently staffed laboratory. The manufacturer's analysis will be accepted, but may be subject to occasional independent checks if required by the Surveyor.

4.2.5 The analysis is to include the content of all the elements detailed in the relevant Sections of the Rules and, where appropriate, the National or International Standard applied.

4.2.6 At the discretion of the Surveyors, a check chemical analysis of suitable samples from products may also be required. These samples are to be taken from the material used for mechanical tests but, where this is not practicable, an alternative procedure for obtaining a representative sample is to be agreed with the manufacturer. For product samples, the permissible limits of deviation from the specified ladle analysis are to be in accordance with an appropriate International or National Standard specification.

4.3 Heat treatment

4.3.1 Materials are to be supplied in the condition specified in, or permitted by, the relevant Chapters of these Rules.

4.3.2 Heat treatment is to be carried out in properly constructed furnaces, which are efficiently maintained and have adequate means for control and recording of temperature. The furnace dimensions are to be such as to allow the whole item to be uniformly heated to the necessary temperature. In the case of very large components, which require heat treatment, alternative methods will be specially considered.

4.3.3 The manufacturer is to maintain the records, including the temperature charts of all heat treatments, for at least seven years.

4.4 Test material

4.4.1 Sufficient test material is to be provided for the preparation of the test specimen detailed in the specific requirements. It is, however, in the interests of manufacturers to provide additional material for any re-tests which may be necessary, as insufficient or unacceptable test material may be a cause for rejection.

4.4.2 The test material is to be representative of the item or batch and is not to be separated until all the specified heat treatment has been completed, except where provision for an alternative procedure is made in subsequent Chapters of these Rules.

4.4.3 All test material is to be selected by the Surveyor or an authorised deputy and identified by suitable markings which are to be maintained during the preparation of the test specimens.

4.5 Mechanical tests

4.5.1 The dimensions, number and direction of test specimens are to be in accordance with the requirements of Chapter 2 and the specific requirements for the product.

4.5.2 Where Charpy impact tests are required, a set of three test specimens is to be prepared and the average energy value is to comply with the requirements of subsequent Chapters. One individual value may be less than the required average value, provided that it is not less than 70 per cent of that value.

4.5.3 In the Rules, mechanical properties are specified in SI units, but alternative units may be used for acceptance testing. In such cases, the specified values are to be converted in accordance with the appropriate conversions given in Table 1.4.1. It is preferred that test results be reported in SI units, but alternative units may be used provided that the test certificate gives, in the same units, the equivalent specification values.

Table 1.4.1 Conversions from SI units to metric and Imperial units

1 N/mm^2 or MPa	=	0,102 kgf/mm^2
1 N/mm^2 or MPa	=	0,0647 tonf/in^2
1 N/mm^2 or MPa	=	0,145 x 10^3 lbf/in^2
1J	=	0,102 kgf m
1J	=	0,738 ft lbs
1 kgf/mm^2	=	9,81 N/mm^2 or MPa
1 tonf/in^2	=	15,4 N/mm^2 or MPa
1 lbf/in^2	=	6,89 x 10^{-3} N/mm^2 or MPa
1 kgf m	=	9,81 J
1 ft lbf	=	1,36 J

4.6 Re-test procedures

4.6.1 Re-test procedures are to be in accordance with the requirements of Ch 2,1.4.

4.7 Rectification of defective material

4.7.1 Small surface imperfections may be removed by mechanical means provided that, after such treatment, the dimensions are acceptable, the area is proved free from defects and the rectification has been completed in accordance with any applicable requirements of subsequent Chapters of these Rules and to the satisfaction of the Surveyor.

4.7.2 The repair of defects by welding, can be accepted only when permitted by the appropriate specific requirements and provided that the agreement of the Surveyor is obtained before the work is commenced. When a repair has been agreed, it is necessary in all cases to prove by suitable methods of non-destructive examination that the defects have been completely removed before welding is commenced. Welding procedures and inspection on completion of the repair, are to be in accordance with the appropriate specific require-ments and are to be to the satisfaction of the Surveyor.

4.7.3 Manufacturers wishing to carry out welding work must have at their disposal the necessary workshops, lifting gear, welding equipment, pre-heating, and where necessary annealing facilities and testing devices, as well as certified welders and supervisors to enable them to perform the work properly. Proof shall be furnished to the Surveyor that these conditions are satisfied before welding work begins.

4.8 Identification of materials

4.8.1 The manufacturer is to adopt a system of identification, which will enable all finished materials to be traced to the original cast, and the Surveyors are to be given full facilities for tracing the material when required. When any item has been identified by the personal mark of a Surveyor, or his deputy, this is not to be removed until an acceptable new identification mark has been made by a Surveyor. Failure to comply with this condition will render the item liable to rejection.

4.8.2 Before any item is finally accepted, it is to be clearly marked by the manufacturer in at least one place with the particulars detailed in the appropriate specific requirements.

4.8.3 Where hard stamps such as the LR brand stamp are issued to manufacturers to carry out the stamping on behalf of LR, the procedure for issue, maintenance and use of stamps is to be agreed in writing.

4.8.4 Hard stamping is to be used except where this may be detrimental to the material, in which case stencilling, painting or electric etching is to be used. Paints used to identify alloy steels are to be free from lead, copper, zinc or tin, i.e., the dried film is not to contain any of these elements in quantities of more than 250 ppm.

4.8.5 Where a number of identical items are securely fastened together in bundles, the manufacturer need only brand the top item of each bundle. Alternatively, a durable label giving the required particulars may be attached to each bundle.

■ *Section 5* Non-destructive examination

5.1 General NDE requirements

5.1.1 Prior to the final acceptance of materials, surface inspection and verification of dimensions, non-destructive examination is to be carried out in accordance with the requirements detailed in this Section and subsequent Chapters of these Rules.

5.1.2 It is the manufacturer's responsibility for maintaining the required tolerances and making the necessary measurements. Periodic surveys by the Surveyor do not absolve the manufacturer from this responsibility.

5.1.3 When there is visible evidence to doubt the soundness of any material or component, such as flaws in test specimens or suspicious surface marks, the manufacturer is expected to prove the quality of the material by a suitable method.

5.1.4 Acceptance criteria are detailed in subsequent Chapters of these Rules. Alternative specifications may be submitted for consideration, provided they demonstrate equivalence to these Rules.

5.2 Personnel qualifications

5.2.1 The shipyard, fabricator or manufacturer is to ensure that personnel carrying out non-destructive examination or interpreting the results of non-destructive examination are qualified to the appropriate level of a nationally recognised scheme such as ISO 9712, EN 473, PCN, ACCP or SNT-TC-1A. Level 1 personnel are not permitted to interpret results to Codes or Standards.

5.2.2 When certification of personnel is made on an in-house basis under a scheme such as SNT-TC-1A, practical examinations are to be relevant to material, product type, joint configuration, material thickness and acceptance criteria of items inspected for Classification purposes.

5.2.3 Personnel qualifications of NDE operators are to be randomly checked by the Surveyor.

5.3 Non-destructive examination methods

5.3.1 Non-destructive examination methods are to comply with the relevant requirements of these Rules.

5.4 Non-destructive examination procedures

5.4.1 All non-destructive examinations are to be carried out to a procedure that is representative of the item under inspection. As a minimum the procedures are to be in accordance with the following:

(a) Procedures are to identify the component to be examined, the NDE method, equipment to be used and the full extent of the examinations including any test restrictions.
(b) Procedures are to specify the qualification and certification requirements of the inspection personnel to be employed.
(c) Procedures are to state the degree of surface preparation required and the methods of preparation to be used before the examinations are made.
(d) Procedures are to state the reference standards for testing and the acceptance criteria to be applied to the results of the inspections.
(e) Procedures are to include the requirement for components to be positively identified and for a datum system or marking system to be applied to ensure repeatability of inspections.
(f) Procedures are to identify any requirements for increasing the extent of applied NDE where defects have been found during spot examination.
(g) Procedures are to identify reporting requirements.
(h) Procedures are to be reviewed by the Surveyor to ensure they are appropriate for the product type.
(j) Procedures for radiography are to specify the acceptable optical density within the area of interest on the radiograph.
(k) The minimum optical density within the area of interest on a radiograph is to be equal to or greater than 2,0 for gamma ray and 1,8 for X-ray. A maximum density of 4,0 is acceptable.
(l) Procedures are to include the method and requirements for equipment calibrations and functional checks.
(m) Procedures are to be approved by an operator qualified to a minimum of Level III in accordance with a recognised standard.
(n) The Surveyor will review procedures for compliance with this Section.

5.4.2 The shipyard, fabricator or manufacturer may submit other Codes or Standards for consideration by LR, providing they are equivalent to these Rules. Where no agreed acceptance standard is in place, the acceptance levels contained in the subsequent Chapters of these Rules are to apply.

5.4.3 In the event that proposed acceptance criteria are not considered to be equivalent to these Rules, the criteria may be submitted for special consideration.

5.5 Non-destructive examination reports

5.5.1 NDE reports are to include all information required to identify how the examination was executed and are to include the following information where appropriate:

(a) Date of test.
(b) Name and qualification of operator with signatures of the operator.
(c) Details of the component identification, description of test location and volume examined.
(d) Heat treatment status.
(e) Weld type, procedure and configuration.
(f) Surface condition.
(g) Test procedure.
(h) Equipment used.
(j) Test results with a map or record of reportable and/or reject indications, giving location, dimensions and nature of indications.
(k) Reference to acceptance criteria and evaluation in accordance to these criteria.
(l) Material type and thickness.
(m) Calibration.

■ *Section 6* References

6.1 General

6.1.1 The locations of National and International Standards referenced in these Rules are shown in Table 1.6.1.

Table 1.6.1 List of National and International Standards (*see continuation*)

Rule reference	Standard
Chapter 1 – General Requirements	ISO 9001: 2008
Chapter 2 – Testing Procedures for Metallic Materials	ISO 6892-1: 2009 ISO 185: 2005 ISO 2566-1: 1999 ISO 148-1: 2009 ISO 7500-1: 2004 ISO 6506-1: 2006 ISO 6506-2: 2006 ISO 6506-3: 2006 ISO 6507-1: 2006 ISO 6507-2: 2006 ISO 6507-3: 2006 ISO 6508-1: 2006 ASTM E23-07a
Chapter 3 – Rolled Steel Plates, Strip, Sections and Bars	EN 10160: 1999 ASTM A578-07 ASTM E112-2010 ASTM E381-01 (2006) ASTM A255-2010
Chapter 4 – Steel Castings	ISO 1161: 1984/Amendment 1: 2007
Chapter 5 – Steel Forgings	ASTM E112-2010
Chapter 8 – Aluminium Alloys	ASTM G66-99 (2005)e1 ASTM G67-04
Chapter 9 – Copper Alloys	ASTM E272-2010 EN 1057: 2006 +A1: 2010
Chapter 10 – Equipment for Mooring and Anchoring	ISO 1704: 2008 ISO 1834: 1999 ISO 4565: 1986 ASTM E112-2010 ASTM E381-01 (2006) ASTM A255-2010
Chapter 11 – Approval of Welding Consumables	ISO 3690: 2000 ISO 10042: 2005 ASTM G48-03 (2009)
Chapter 12 – Welding Qualifications	ISO 6947: 2011 ISO 5817: 2007 ISO 6520-1: 2007 ISO 6507-1: 2005 ISO 10042: 2005
Chapter 13 – Requirements for Welded Construction	ISO 9712/Cor1: 2006 EN 473: 2008 ISO 6520-1: 2007 SNT TC-1A-2011 AWS D3.6M:2010 ISO 10042: 2005

Table 1.6.1 List of National and International Standards (*conclusion*)

Rule reference	Standard
Chapter 14 – Plastics Materials	ISO 527-2: 1993/corr1:1994 ISO 178: 2010 ISO 62: 2008 ISO 75-2: 2004 ISO 604: 2002 ISO 527-4: 1997 ISO 14125: 1998/ amd1:2011 ISO 14130: 1997/ corr1:2003 ISO 1172: 1996 ISO 1922- 2001 ASTM C273/C273M-06 2011 ASTM C393/C393M-2011 ISO 845- 2006 ASTM C297/C297M-04 ISO 844-2007 ISO 1922-2001 ISO 180-2000 ASTM D2583-07 BS 2782-10 Method 1001: 1977 ISO 175: 2010 BS 1088-1: 2003 BS 1088-2: 2003

Section 1
General requirements for testing

1.1 Preparation of test specimens

1.1.1 The requirements specified below detail all the tests that may be applied to metallic materials. The specific tests and the test specimen types required for each material type, grade and product type are detailed in the subsequent Chapter of these Rules.

1.1.2 Where test material is cut from products by shearing or flame cutting, a reasonable margin is required to allow sufficient material to be removed from the cut edges during machining of the test specimens.

1.1.3 Test specimens are to be prepared in such a manner that they are not subjected to any significant work hardening, cold straining or heating during straightening or machining.

1.1.4 Test samples are not to be removed from the material they represent until heat treatment is complete. For castings in cases where test samples are separately cast, the castings and samples are to be heat treated together.

1.1.5 Dimensional tolerances are to comply with a relevant ISO specification.

1.2 Testing machines

1.2.1 All tests are to be carried out by competent personnel. Testing machines are to be maintained in a satisfactory and accurate condition and are to be recalibrated at approximately annual intervals. This calibration is to be carried out by organisations of standing that have been approved or recognised by a National Authority and are to be to the satisfaction of the Surveyor. A record of all calibrations is to be kept available in the test house.

1.2.2 Tensile testing machine load cells are to be calibrated with an accuracy of ± one per cent in accordance with ISO 7500-1 or another recognised National Standard.

1.2.3 Impact tests are to be carried out on Charpy V-notch machines calibrated to ISO 148 or ASTM E23 dependent on the testing machine type. The testing machines are to be calibrated using either a direct or indirect method. Other National Standards equivalent to ISO 148 may be considered.

1.2.4 Hardness testing machines, together with their associated measuring microscopes, are to be directly and indirectly calibrated to ISO 6506-2, 6507-2 or equivalent standards applicable to the type of hardness test. Other National Standards equivalent to ISO 6507-2 and 6506-2 standards may be considered. Routine hardness checks with standard hardness blocks calibrated to ISO 6506-3 or ISO 6507-3 or equivalent are to be carried out at a frequency which demonstrates calibration consistency.

1.3 Discarding of test specimens

1.3.1 If a test specimen fails because of faulty preparation or incorrect operation of the testing machine it may be discarded and replaced by a new test specimen prepared from material adjacent to the original test.

1.3.2 In addition to the discarding of test specimens as indicated in 1.3.1, a tensile test specimen may also be discarded when the specified minimum elongation is not obtained and the distance between the fracture and the nearest gauge mark is less than one-quarter of the gauge length.

1.4 Re-testing procedures

1.4.1 Where the result of any test, other than an impact test, does not comply with the requirements, two additional tests of the same type are to be made from the same test sample, or if sufficient material is not available, a further representative sample taken from the item under test. For acceptance of the material, satisfactory results are to be obtained from both of these additional tests.

1.4.2 Where the result of any test taken from a weld procedure approval test, other than an impact test, does not comply with the requirements, two additional tests of the same type are to be made from the same weld test assembly. Where insufficient original welded assembly is available, a new assembly is to be prepared using the same conditions as the original test weld. For acceptance, satisfactory results are to be obtained from both of these additional tests.

1.4.3 Where the result of any test taken from a welding consumable approval test, other than an impact test, does not comply with the requirements, two additional tests of the same type are to be made from the same weld test assembly. Where insufficient original welded assembly is available, a new assembly is to be prepared using welding consumables from the same batch. If the new assembly is made with the same procedure (particularly the same number of runs) as the original assembly, only the duplicate re-test specimens need be prepared and tested. For acceptance of a weld consumable batch, satisfactory results are to be obtained from both of these additional tests.

1.4.4 Where the results from a set of three impact test specimens do not comply with the requirements, an additional set of three impact test specimens may be tested provided that, of the original set tested, not more than two individual values are less than the required average value and, of these, not more than one is less than 70 per cent of this average value. The results obtained are to be combined with the original results to form a new average which, for acceptance, is to be not less than the required average value. Additionally, for these combined results, not more than two individual values are to be less than the required average value and, of these, not more than one is to be less than 70 per cent of this average value.

1.4.5 The additional tests detailed in 1.4.1 and 1.4.2 are, where possible, to be made on material adjacent to the original samples. For castings, where insufficient material remains in the original test samples, the additional test may be made on other test samples representative of the castings. *See also* 1.3 for discarding of test specimens.

1.4.6 When unsatisfactory results are obtained from tests representative of a batch of material, the item or piece from which the tests were taken is to be rejected. The remainder of the material in the batch may be accepted provided that two further items or pieces are selected and tested with satisfactory results. If the tests from one or both or these additional items or pieces give unsatisfactory results, the batch is to be rejected.

1.4.7 When a batch of material is rejected, the remaining items or pieces in the batch may be resubmitted individually for test, and those which give satisfactory results may be accepted.

1.4.8 At the option of the manufacturer, rejected material may be resubmitted as another grade and may then be accepted, provided that the test results comply with the appropriate requirements.

1.4.9 When material which is intended to be supplied in the ‘as-rolled’ or ‘hot-finished’ condition fails test, it may be suitably heat treated and resubmitted for test. Similarly, materials supplied in the heat treated condition may be reheat treated and resubmitted for test. Unless otherwise agreed by the Surveyor, such reheat treatment is to be limited to one repeat of the final heat treatment cycle.

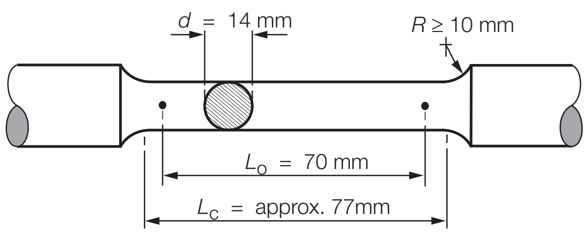
■ *Section 2* **Tensile tests**

2.1 Dimensions of test specimens

2.1.1 Proportional test specimens with a gauge length L_o of $5{,}65\sqrt{S_o}$ or $5d$, where S_o is the cross-sectional area, d the diameter and L_c the parallel test length, have been adopted as the standard form of test specimen, and in subsequent Chapters in these Rules the minimum percentage elongation values are given for test specimens of these proportions.

2.1.2 The gauge length is to be greater than 20 mm and may be rounded off to the nearest 5 mm provided that the difference between the adjusted gauge length and the calculated one is less than 10 per cent of the calculated gauge length.

2.1.3 For forgings and castings (excluding those in grey cast iron) proportional test specimens of circular cross-section are to be machined to the dimensions shown in Fig. 2.2.1.

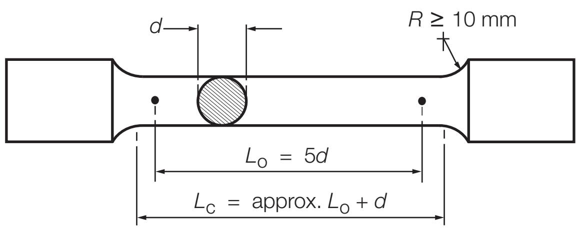


NOTE: For nodular cast iron and materials with a specified elongation less than 10%, $R \geq 20$ mm

Fig. 2.2.1
Test specimen dimensions for forgings and castings – I

2.1.4 For hot rolled bars and similar products, the test specimens are to be as in Fig. 2.2.1, except that for small sizes they may consist of a suitable length of bar or other product tested in the full cross-section.

2.1.5 As an alternative to 2.1.3 and 2.1.4, proportional or non-proportional test specimens of other dimensions may be used, subject to any requirements for minimum cross-sectional area given in subsequent Chapters of these Rules. Where the size of proportional test specimens is other than as shown in Fig. 2.2.1, the general dimensions are to conform with Fig. 2.2.2.



NOTE: For nodular cast iron and materials with a specified elongation less than 10%, $R \geq 1,5d$

Fig. 2.2.2
Test specimen dimensions for forgings and castings – II and aluminium alloys

2.1.6 For plates, strip and sections, the test specimens are to be machined to the dimensions shown in Fig. 2.2.3 or Fig. 2.2.4. Where the capacity of the available testing machine is insufficient to allow the use of a test specimen of full thickness, this may be reduced by machining one of the rolled surfaces. Alternatively, for materials over 40 mm thick, test specimens of circular cross-section machined to the dimensions shown in Fig. 2.2.1 may be used. The axes of these test specimens are to be located at approximately one quarter of the thickness from one of the rolled surfaces.

2.1.7 As an alternative to 2.1.6, test specimens with a width of other than 25 mm may be used subject to any requirements for minimum cross-sectional area given in subsequent Chapters of these Rules. A ratio of width/thickness of 8:1 should not be exceeded.

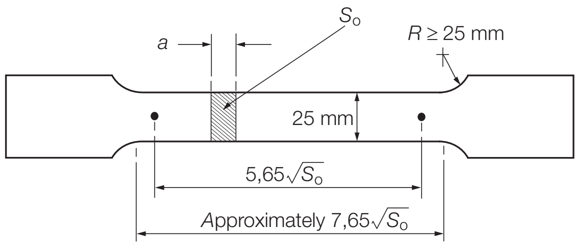
2.1.8 For pipes and tubes, the test specimens may consist of a suitable length tested in full cross-section with the ends plugged. The gauge length is to be $5,65\sqrt{S_o}$ or 50 mm, and the length of the test specimen between the grips or plugs, whichever is the smaller, is to be not less than the gauge length plus D, where D is the external diameter. Alternatively, test specimens may be prepared from strips cut longitudinally and machined to the dimensions shown in Fig. 2.2.5 or Fig. 2.2.6. The parallel test length is not to be flattened, but the enlarged ends may be flattened for gripping in the testing machine.
The cross-sectional area of this type of test specimen is to be calculated from:

$S_o = ab$

where

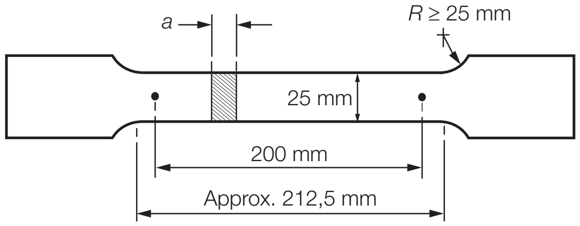
S_o = cross-sectional area
a = average radial thickness
b = average width

Test specimens of circular cross-section may also be used provided that the wall thickness is sufficient to allow the machining of such specimens to the dimensions shown in Fig. 2.2.1, with their axes located at the mid-wall thickness.



a = thickness of material

Fig. 2.2.3
Test specimen dimensions for plates, strip and sections – I and aluminium alloys



a = thickness of material

Fig. 2.2.4
Test specimen dimensions for plates, strip and sections – II

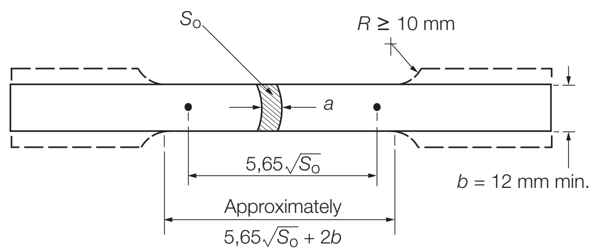


Fig. 2.2.5
Test specimen dimensions for pipes and tubes – I

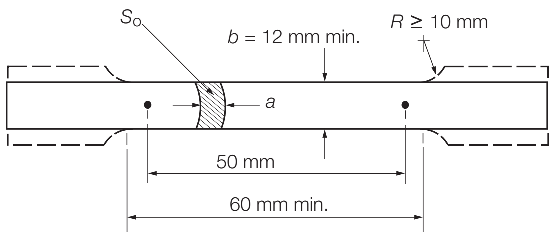


Fig. 2.2.6
Test specimen dimensions for pipes and tubes – II

2.1.9 For wire, the test specimen may consist of a suitable length tested in full cross-section. The gauge length is to be 200 mm and the parallel test length 250 mm.

2.1.10 For grey iron castings, the test specimens are to be machined to the dimensions shown in Fig. 2.2.7 or Fig. 2.2.8.

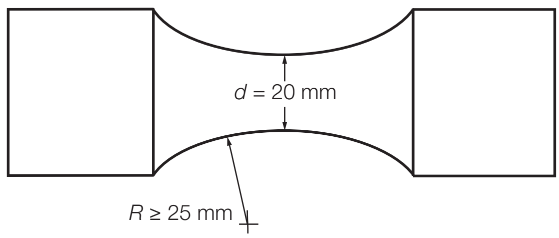


Fig. 2.2.7
Test specimen dimensions for grey iron castings – I

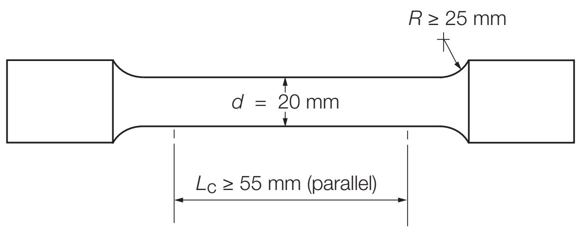


Fig. 2.2.8
Test specimen dimensions for grey iron castings – II

2.1.11 For aluminium alloy plates and sections of thickness, *a*, less than or equal to 12,5 mm; the dimensions of rectangular cross-sectioned test specimens are to be as shown in Fig. 2.2.3. The rectangular cross-sectioned test specimen surfaces should remain as rolled/extruded. Where the thickness, *a*, is greater than 12,5 mm the test specimens are to be of round type as shown in Fig. 2.2.2.

2.1.12 Deposited weld metal tensile test specimens are to be machined to the dimensions shown in Fig. 2.2.9, and may be heated to a temperature not exceeding 250°C for a period not exceeding 16 hours for hydrogen removal, prior to testing.

2.1.13 Butt weld tensile test specimens are to be machined to the dimensions shown in Fig. 2.2.10. For thicknesses of more than 2 mm, the test width is to be 25 mm. For thicknesses less than 2 mm, the test width is to be reduced to 12 mm. The upper and lower surfaces of the weld are to be filed, ground or machined flush with the surface of the plate.

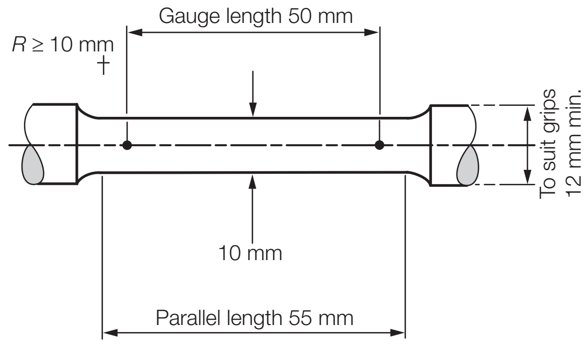


Fig. 2.2.9
Test specimen for deposited weld metal tensile

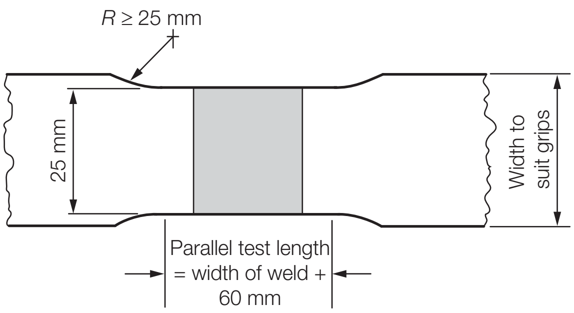


Fig. 2.2.10 Test specimen for butt weld

2.1.14 Through-thickness tensile test specimens may be, at the option of the steelmaker, either plain test specimens or test specimens with welded extensions in accordance with a Recognised Standard. The extension pieces are to be of steel with a tensile strength exceeding that of the plate to be tested and may be attached to the plate surfaces by manual, resistance or friction welding carried out in such a way as to ensure a minimal heat affected zone.

2.1.15 Tolerances on tensile specimen dimensions are to be in accordance with ISO 6892-1 or another Recognised Standard as appropriate.

2.2 Definition of yield stress for steel

2.2.1 The yield phenomenon is not exhibited by all the steels detailed in these Rules but, except for austenitic and duplex stainless steels, the term 'yield stress' is used throughout when requirements are specified for acceptance testing at ambient temperature. For the purposes of the Rules, the terms 'yield stress' and 'yield strength' are to be regarded as synonymous.

2.2.2 Where reference is made to 'yield stress' in the requirements for carbon, carbon-manganese and alloy steel products and in the requirements for the approval of welding consumables, either the upper yield stress or, where this is not clearly exhibited, the 0,2 per cent proof stress or the 0,5 per cent proof stress under load is to be determined. In cases of dispute, the 0,2 per cent proof stress is to be determined.

2.2.3 For austenitic and duplex stainless steel products and welding consumables, both the 0,2 and the 1,0 per cent proof stresses are to be determined.

2.3 Procedure for testing at ambient temperature

2.3.1 Except as provided in 2.3.5, the elastic stress rate for the determination of the upper yield for steels and copper alloys is to be between 6 and 60 N/mm^2 per second and between 2 and 20 N/mm^2 per second for aluminium. After reaching the yield or proof load, the straining rate may be increased to a maximum of 0,008s^{-1} for the determination of the tensile strength.

2.3.2 For steel, the upper yield stress is to be calculated from:

(a) the value of stress measured at the commencement of plastic deformation, or

(b) on a load/extension diagram using the value of stress measured at the first peak obtained during yielding even when the peak is equal to or less than any subsequent peaks observed during plastic deformation at yield.

2.3.3 When a well defined yield point cannot be obtained, the 0,2 or 1,0 per cent proof stress (non-proportional elongation) is to be determined from an accurate load/extension diagram by drawing a line parallel to the straight elastic portion and a distance from it where the amount represents 0,2 or 1,0 per cent of the extensometer gauge length. The point of intersection of this line with the plastic portion of the diagram represents the proof load, from which the 0,2 or 1,0 per cent proof stress can be calculated.

2.3.4 For stainless steels, the 1,0 per cent proof stress and/or 0,2 per cent proof stress is specified as required by the relevant Chapters in these Rules.

2.3.5 For the determination of the tensile strength of flake graphite cast iron, the stress rate is not to exceed 10 N/mm^2 per second.

2.3.6 A measured elongation value is to be regarded as valid only if the fracture occurs within the gauge length and at least the following distances from the gauge marks:

Round test specimen:	1,25d
Flat test specimen:	a plus width of specimen

The measurement is valid irrespective of the position of the fracture, if the percentage elongation after fracture reaches at least the specified value, and this is to be stated in the test report.

2.4 Equivalent elongations

2.4.1 When a gauge length other than $5{,}65\sqrt{S_o}$ is used, the equivalent percentage elongation value is to be calculated using the following formula:

$$A = \frac{A_R}{2}\left(\frac{L_o}{\sqrt{S_o}}\right)^{0{,}40}$$

where

A_R = actual measured percentage elongation of test specimen
S_o = actual cross-sectional area of test specimen
L_o = actual gauge length of test piece
A = equivalent percentage elongation for a test specimen with a gauge length of $5{,}65\sqrt{S_o}$.

2.4.2 Alternatively, where a number of test specimens of similar material and dimensions are involved, the actual percentage elongation values may be recorded, provided that the equivalent specified minimum elongation value appropriate for the test specimen dimensions is calculated from the formula in 2.4.1 and is recorded on the test certificate.

2.4.3 For proportional test specimens having a gauge length other than $5{,}65\sqrt{S_o}$, the equivalent elongation may be calculated using the following factors (d is the diameter of the test specimen):

Actual gauge length	Factor for equivalent elongation on $5{,}65\sqrt{S_o}$
$4\sqrt{S_o}$	x 0,870
$8{,}16\sqrt{S_o}$	x 1,158
$11{,}3\sqrt{S_o}$	x 1,317
4d	x 0,916
8d	x 1,207

2.4.4 For non-proportional test specimens with gauge lengths of 50 mm and 200 mm, the equivalent elongation values tabulated in ISO 2566 are to apply.

2.4.5 The above conversions are reliable only for carbon, carbon-manganese and low alloy steels with a tensile strength not exceeding 700 N/mm^2 in the hot rolled, annealed, normalised, or normalised and tempered condition.

2.4.6 For alloy steels in the quenched and tempered condition, the following conversions may be used for proportional test specimens with a gauge length of $4\sqrt{S_o}$:

Actual percentage elongation on $4\sqrt{S_o}$	Equivalent elongation on $5{,}65\sqrt{S_o}$
22	17
20	15
18	13
17	12
16	12
15	11
14	10
12	8
10	7
8	5

2.4.7 Any proposals to use conversion factors for equivalent elongation values for the following materials are to be agreed with the Surveyors:

(a) Carbon, carbon-manganese and alloy steels in the normalised or normalised and tempered condition with a tensile strength exceeding 700 N/mm^2.
(b) Cold-worked steels.
(c) Austenitic stainless steels.
(d) Non-ferrous alloys.

2.5 Procedure for testing at elevated temperatures

2.5.1 The test specimens used for the determination of lower yield or 0,2 per cent proof stress at elevated temperatures are to have an extensometer gauge length of not less than 50 mm and a cross-sectional area of not less than 65 mm^2. Where, however, this is precluded by the dimensions of the product or by the test equipment available, the test specimen is to be of the largest practicable dimensions.

2.5.2 The heating apparatus is to be such that the temperature of the specimen during testing does not deviate from that specified by more than ±5°C.

2.5.3 The straining rate when approaching the lower yield or proof load is to be controlled within the range 0,1 to 0,3 per cent of the extensometer gauge length per minute.

2.5.4 The time intervals used for estimation of strain rate from measurements of strain are not to exceed 6 seconds.

■ *Section 3* Impact tests

3.1 Dimensions of test specimens

3.1.1 Impact tests are to be of the Charpy V-notch type. The test specimens are to be machined to the dimensions and tolerances given in Table 2.3.1 and are to be carefully checked for dimensional accuracy.

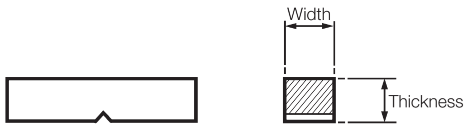
3.1.2 For material under 10 mm in thickness, the largest possible size of standard subsidiary Charpy V-notch test specimen is to be prepared with the notch cut on the narrow face. Generally, impact tests are not required when the thickness of the material is less than 6 mm.

3.2 Testing procedures

3.2.1 All impact tests are to be carried out on Charpy machines approved by Lloyd's Register (hereinafter referred as LR) and having a striking energy of not less than 150 J.

Table 2.3.1 Dimensions and tolerances for Charpy V-notch impact test specimens

Dimension	Nominal	Tolerance
Length, mm	55	±0,60
Width, mm – standard specimen	10	±0,11
– standard subsidiary specimen	7,5	±0,11
– standard subsidiary specimen	5	±0,06
Thickness, mm	10	±0,06
Angle of notch	45°	±2°
Depth below notch, mm	8	±0,06
Root radius, mm	0,25	±0,025
Distance of notch from end of test specimen, mm	27,5	±0,42
Angle between plane of symmetry of notch and longitudinal axis of test specimen	90°	±2°



3.2.2 Charpy V-notch impact tests may be carried out at ambient or lower temperatures in accordance with the specific requirements given in subsequent Chapters of these Rules. Where the test temperature is other than ambient, the temperature of the test specimen is to be controlled to within ±2°C for sufficient time to ensure uniformity throughout the cross-section of the test specimen, and suitable precautions are to be taken to prevent any significant change in temperature during the actual test. In cases of dispute, ambient temperature is to be considered as 18°C to 25°C.

3.2.3 For acceptance, the average energy value for a set of three impact tests must be equal to or greater than the appropriate specified minimum average value. Additionally, only one individual value may be less than the required average value but not less than 70 per cent of this average value.

3.2.4 Where standard subsidiary Charpy V-notch test specimens are necessary, the minimum energy values required are to be reduced as follows:

Specimen 10 x 7,5 mm: 5/6 of tabulated energy.
Specimen 10 x 5 mm: 2/3 of tabulated energy.

3.2.5 When reporting results, the specimen dimensions and the units used for expressing the energy absorbed (Joules) and the testing temperature are to be clearly stated.

Section 4
Ductility tests for pipes and tubes

4.1 Bend tests

4.1.1 The test specimens are to be cut as circumferential strips of full wall thickness and with a width of not less than 40 mm. For thick walled pipes, the thickness of the test specimens may be reduced to 20 mm by machining. The edges of the specimens may be rounded to a radius of 1,6 mm.

4.1.2 Testing is to be carried out at ambient temperature, and the specimens are to be doubled over a former whose diameter is to be in accordance with the specific requirements for the material. For submerged arc welded tube the test piece is to be bent with the root of the weld in tension. For other tubes, the test piece is to be bent in the original direction of curvature. In all cases, the welds are to be in the middle of the test specimen. The test is considered to be satisfactory if, after bending, the specimens are free from cracks and laminations. Small cracks at the edges of the test specimens are to be disregarded.

4.2 Flattening tests

4.2.1 Ring test specimens are to be cut with the ends perpendicular to the axis of the pipe or tube. The length of the specimen is to be equal to 1,5 times the external diameter of the pipe or tube, but is to be not less than 10 mm or greater than 100 mm. Alternatively, the length of the test specimen may be 40 mm irrespective of the external diameter.

4.2.2 Testing is to be carried out at ambient temperature and is to consist of flattening the specimens in a direction perpendicular to the longitudinal axis of the pipe. Flattening is to be carried out between two plain parallel and rigid platens which extend over both the full length and the width after flattening of the test specimen. Flattening is to be continued until the distance between the platens, measured under load, is not greater than the value given by the formula:

$$H = \frac{t\,(1 + C)}{C + \frac{t}{D}}$$

where
H = distance between plates, in mm
t = specified thickness of the pipe, in mm
D = specified outside diameter, in mm
C = a constant dependent on the steel type and detailed in the specific requirements

After flattening, the specimens are to be free from cracks or other flaws. Small cracks at the ends of the test specimens may be disregarded.

4.2.3 For welded pipes or tubes, the weld is to be placed at 90° to the direction of flattening.

4.3 Drift expanding tests

4.3.1 The test specimens are to be cut with the ends perpendicular to the axis of the tube. The edges of the end to be tested may be rounded by filing.

4.3.2 For metallic tubes, the length of the specimen is to be at least 1,5 times the external diameter of the tube except when a mandrel with an included angle of 30° is used, in which case the length of the specimen is to be twice the external diameter of the tube. In all cases the length of section remaining cylindrical after test is not be less than 0,5 times the external diameter.

4.3.3 Testing is to be carried out at ambient temperature and is to consist of expanding the end of the tube symmetrically by means of a hardened conical steel mandrel having a total included angle of 30°, 45° or 60°, *see* Fig. 2.4.1. The mandrel is to be forced into the test specimen at a rate not exceeding 50 mm/min until the percentage increase in the outside diameter of the end of the test specimen is not less than the value given in the specific requirements for boiler and superheater tubes, *see* Chapter 6. The mandrel is to be lubricated, but there is to be no rotation of the tube or mandrel during the test. The expanded portion of the tube is to be free from cracks or other flaws.

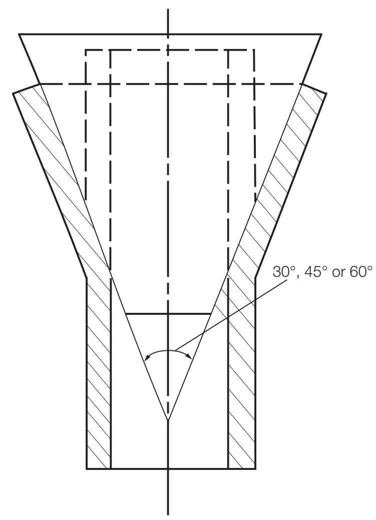


Fig. 2.4.1 Drift expanding test

4.4 Flanging tests

4.4.1 The test specimens are to be cut with the ends perpendicular to the axis of the tube. The length of the specimens is to be at least equal to the external diameter of the tube and such that after testing the portion that remains cylindrical is not less than half the external diameter. The edges of the end to be tested may be rounded by filing.

4.4.2 Testing is to be carried out at ambient temperature and is to consist of flanging the end of the tube symmetrically by means of hardened conical steel mandrels. The rate of flanging is not to exceed 50 mm/min.

4.4.3 The first stage of flanging is to be carried out with a conical angled mandrel having an included angle of approximately 90°, *see* Fig. 2.4.2(a). The completion of the test is achieved with a second forming tool as shown in Fig. 2.4.2(b). The mandrels are to be lubricated and there is to be no rotation of the tube or mandrels during the test. The test is to continue until the drifted portion has formed a flange perpendicular to the axis of the test specimens. The percentage increase in the external diameter of the end of the specimens is to be not less than the value given in the specific requirements for boiler and superheater tubes, *see* Chapter 6. The cylindrical and flanged portion of the tube is to be free from cracks or other flaws.

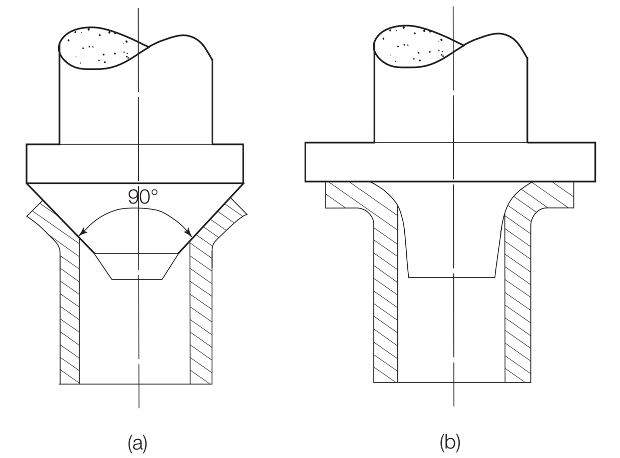


Fig. 2.4.2 Flanging test

■ *Section 5* Embrittlement tests

5.1 Temper embrittlement tests

5.1.1 The test material is to be heat treated in accordance with the specification except that after tempering:

(a) half the material is to be water quenched;

(b) the other half is to be cooled from the tempering temperature to 300°C at a rate not exceeding 10°C per minute.

5.1.2 Impact tests in accordance with Section 3 are to be made on the material in each condition at temperatures over a range wide enough to establish the upper and lower shelf energies and temperatures, tests being made at no less than three intermediate temperatures.

5.1.3 A set of three specimens is to be tested at each temperature. The results are to be plotted separately for each condition, in the form illustrated in Fig. 2.5.1. In addition, the test temperatures, proportions of crystallinity and absorbed energies for all the specimens tested are to be reported.

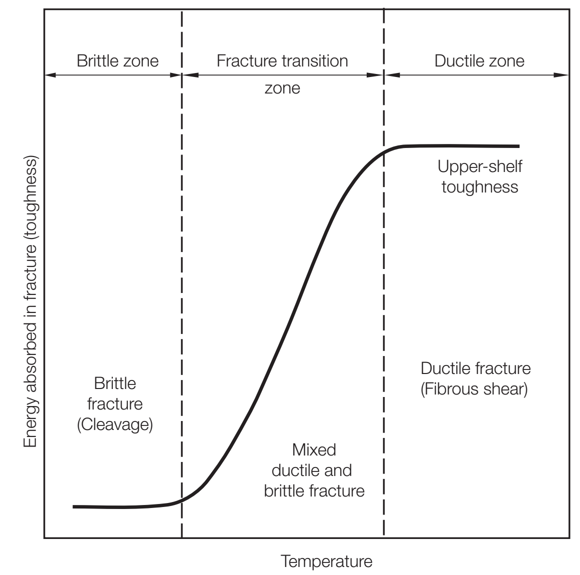


Fig. 2.5.1 Idealised transition curve

5.1.4 The transition temperature for each condition is to be taken as the mid-temperature of the fracture transition zone. The difference between the two transition temperatures is to be reported.

5.2 Strain age embrittlement tests

5.2.1 The test material is to be heat treated in accordance with the specification and then subjected to five per cent strain. Half of the test material is then to be heated to 250°C and held for one hour.

5.2.2 Impact tests in accordance with 5.1.2 are to be made in both the strained and unstrained conditions.

5.2.3 The tests are to comply with 5.1.3.

5.2.4 The test results are treated in accordance with 5.1.4.

5.3 Hydrogen embrittlement tests

5.3.1 Two specimens are to be tested. The specimens are to be of a diameter of 20 mm. Where this is not practicable a diameter of 14 mm may be accepted.

5.3.2 One specimen is to be tested within a maximum of 3 hours after machining. Where the specimen diameter is 14 mm, the time limit is 1,5 hours. Alternatively, the specimen may be cooled to –60°C immediately after machining and kept at that temperature for a maximum period of 5 days before being tested.

5.3.3 The other specimen is to be tested after baking at 250°C for 4 hours. Where the specimen diameter is 14 mm the baking time is to be 2 hours.

5.3.4 A strain rate not exceeding $0{,}0003s^{-1}$ is to be used during the entire test, until fracture occurs.

5.3.5 Tensile strength, elongation and reduction of area are to be reported.

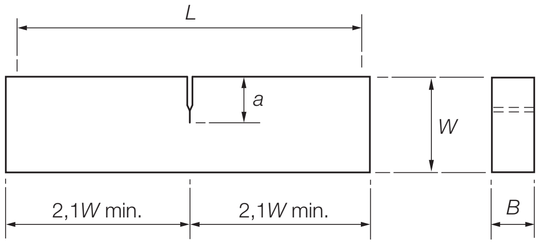
5.3.6 The ratio Z_1/Z_2 is to be reported, where Z_1 is the reduction in area without baking and Z_2 the reduction in area after baking.

Section 6
Crack tip opening displacement tests

6.1 Dimensions of test specimens

6.1.1 Unless agreed otherwise, tests are to be made on specimens of the full section thickness and which conform to a nationally agreed standard.

6.1.2 Normally the specimens are to be rectangular with the main dimensions as indicated in Fig. 2.6.1 and are to be tested in three point bending.

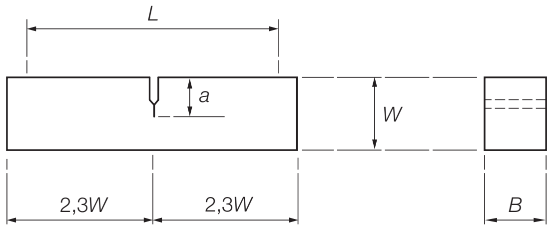


B = thickness
W = width = $2B$
a = effective crack length = $0{,}45W$ to $0{,}55W$
L = loading span = $4W$

Fig. 2.6.1
Outline dimensions of the preferred specimen

6.1.3 A subsidiary specimen as in Fig. 2.6.2 may be used by agreement.

6.1.4 In each case the notch is to be positioned at the centre of the loading span; its root radius is not to exceed 0,10 mm. The notch is to be extended by the generation of a fatigue crack to give an effective crack length of the dimension *a*. For this purpose, the fatigue stress ratio, R_1, is to be within the range 0 to 0,1 and the fatigue intensity is not to exceed $0{,}63\sigma_\gamma B^{1/2}$ where σ_γ is the 0,2 per cent proof stress at the test temperature.



B = thickness
W = width = B
a = effective crack length (to be agreed between the purchaser and manufacturer)
L = loading span = $4W$

Fig. 2.6.2
Outline dimensions of the subsidiary specimen

6.2 Test equipment

6.2.1 Whenever possible, tests are to be made using machines operating under displacement control. The type of control is to be recorded.

6.2.2 The test equipment is to be calibrated annually.

6.2.3 The crack opening displacement gauge is to have an accuracy of at least one per cent. It is to be calibrated at least once every day of testing and at intervals of no more than 10 tests. It should be demonstrated that the calibration is satisfactory for the test conditions.

6.3 Testing procedures

6.3.1 Tests are to be made in a recognised test house in accordance with a nationally accepted standard.

6.3.2 Unless otherwise agreed, all tests on unwelded wrought material are to be made on specimens taken transverse to the principal working direction and are to be through-thickness notched.

6.3.3 Where tests are made on weld material, the fatigue crack should be arranged to sample the maximum amount of unrefined weld metal.

6.3.4 Where tests are made on the Heat Affected Zone (H.A.Z.) of a weld, a K or single bevel weld preparation is recommended. The region of lowest fracture toughness in the Heat Affected Zone should be identified for the particular steel and weld procedure by means of preliminary tests. The fatigue crack is to be accurately positioned to sample as high a proportion of this critical region as possible and after testing has been completed, the specimen is to be sectioned to check that this has been achieved. Sufficient tests should be made to ensure that the critical region has been sampled in at least three specimens.

6.3.5 At least three valid tests are to be made for each material condition. Invalid tests are to be disregarded and the tests repeated.

6.3.6 Local pre-compression of the test specimen ahead of the notch is acceptable in order to provide an acceptably even fatigue crack front.

6.3.7 The temperature of the test piece is to be measured to within ±2°C over the range minus 196°C to +200°C and to within ±5°C outside this range. The temperature should be measured at a point on the specimen not farther than 2 mm away from the crack tip.

6.4 Validity requirements

6.4.1 The test is to be regarded as invalid if:

(a) the fatigue crack front is not in a single plane;
(b) any part of the fatigue crack surface lies in a plane whose angle with the plane of the notch exceeds 10°;
(c) the length of any part of the fatigue crack is less than 0,025*W* or 1,25 mm, whichever is the greater;
(d) the difference between the maximum and minimum lengths of the fatigue crack exceeds 0,1*W*;
(e) the difference between any two of the lengths of the fatigue crack at 0,25*B*, 0,5*B* and 0,75*B* exceeds 0,05*W*.

6.4.2 In addition, for tests on welds and Heat Affected Zones (H.A.Z.), the following criteria are to be complied with:

(a) Weld metal. The fatigue crack front shall not extend outside the weld metal deposit and 80 per cent should be within 2 mm of the fusion line.
(b) Grain coarsened H.A.Z.. The fatigue crack should be within 0,5 mm of the fusion line and should sample all of the grain coarsened H.A.Z. present. However, if fusion line irregularities prevent this, a sample including as much grain coarsened H.A.Z. as possible may be accepted.
(c) Subcritical/intercritical H.A.Z. boundary. The fatigue crack is to sample the boundary between the subcritical and intercritical regions of the H.A.Z. However, if fusion line irregularities prevent this, a sample including as much relevant microstructure as possible may be accepted.

6.5 Test reports

6.5.1 The test report is to include:

(a) details of the material, its condition and size;
(b) the thickness and width of the test specimen;
(c) the fatigue pre-cracking conditions;
(d) the test temperature and environment;
(e) the test machine control system and rate of change of displacement or load;
(f) crack length measurements;
(g) force/displacement records, preferably in the form of an autographic record;
(h) the critical crack opening displacement;
(j) a photograph of the fracture;
(k) any observation on the fracture surface.

Section 7 **Bend tests**

7.1 Dimensions of test specimens

7.1.1 Flat bend test specimens are to be of rectangular cross-section with dimensions as defined in Fig. 2.7.1.

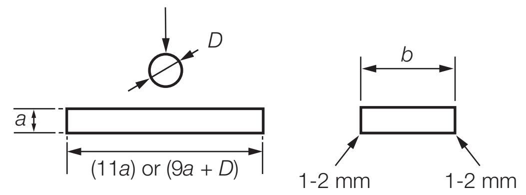


Fig. 2.7.1 Bend test specimen

7.1.2 For plates, sections and strip the dimensions shall be full thickness and width 30 mm. Where the rolled thickness exceeds 25 mm the compression face may be reduced to 25 mm.

7.1.3 For forgings, castings and semi-finished products the thickness shall be 20 mm and width 25 mm.

7.1.4 Butt weld face and root bend test specimens are to be 30 mm in width and of the full plate thickness. Where the thickness exceeds 25 mm, two side bend test specimens may be tested in place of the face and root specimens specified. The side bend specimens should be 10 mm minimum thickness. The upper and lower surfaces of the weld are to be filed, ground or machined flush with the surface of the plate.

7.1.5 The edges on the tension side of bend samples are to be rounded to a radius of 1 to 2 mm.

7.2 Testing procedures

7.2.1 The bend sample is plastically deformed by plunging a mandrel between two fixed points as shown in Fig. 2.7.2.

7.2.2 For aluminium welds a guided bend is required to ensure even deformation as shown in Fig. 2.7.3.

7.2.3 Bend tests are to be conducted at ambient temperature at the highest convenient rate of bending (but not impact).

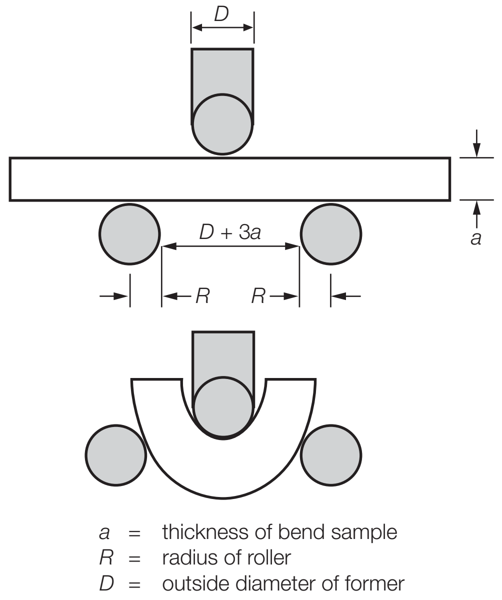


Fig. 2.7.2 Bend test

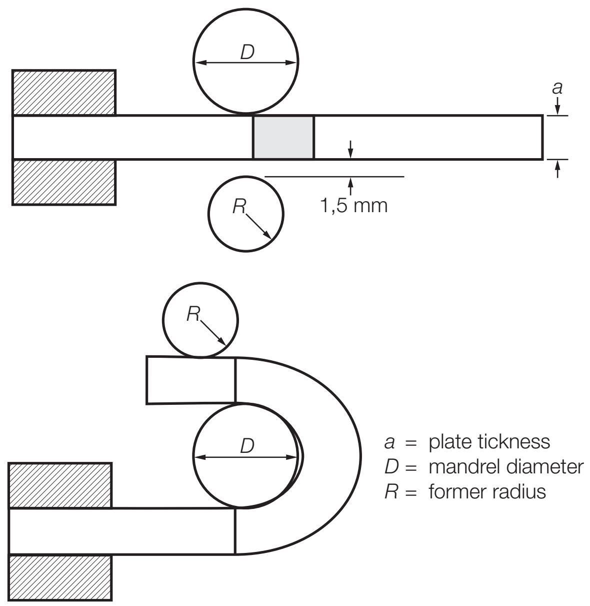


Fig. 2.7.3 Guide bend test for aluminium

Section 8
Hardness testing

8.1 Dimensions of test specimens

8.1.1 Test pieces must be held rigidly in relation to the indenter and located such that the surface to be tested is at right angles to the axis of the indenter.

8.1.2 The surface finish of the test piece is to be such as to be able to measure the indent accurately.

8.2 Testing procedure

8.2.1 Hardness testing is to be carried out according to ISO 6506-1, ISO 6507-1 or equivalent for the type of hardness test.

Section 9
Corrosion tests

9.1 Intergranular corrosion test

9.1.1 For all products other than pipes, the material for the test specimens is to be taken adjacent to that for the tensile test and is to be machined to suitable dimensions for either a round or rectangular section bend test. The diameter or thickness is to be not more than 12 mm, and the total surface area is to be between 1500 mm^2 and 3500 mm^2.

9.1.2 For pipes with an outside diameter not exceeding 40 mm, the test specimens are to consist of a full cross-section. For larger pipes, the test specimens are to be cut as circumferential strips of full wall thickness and having a width of not less than 12,5 mm. In both cases the total surface area is to be between 1500 mm^2 and 3500 mm^2.

9.1.3 Specimens are to be heated to a temperature of 700 ± 10ºC for 30 minutes, followed by rapid cooling in water. They are then to be placed on a bed of copper turnings (50 g per litre of test solution) and immersed for 15 to 24 hours in a boiling solution of the following composition:

- 100 g of hydrated copper sulphate granules ($CuSO_4 . 5H_2O$)
- 184 g (100 ml) sulphuric acid (density 1,84 g/ml) added dropwise to distilled water to make 1 litre of solution.

Precautions are to be taken during boiling to prevent concentration of the solution by evaporation.

9.1.4 After immersion, the full cross-section test specimens from pipes are to be subjected to a flattening test in accordance with Ch 2,4.2. All other test specimens are to be bent, at ambient temperature, through 90º over a former with a diameter equal to twice the diameter or thickness of the test specimen.

9.1.5 After flattening or bending, the test specimens are to be free from cracks on the outer, convex surface.

Rolled Steel Plates, Strip, Sections and Bars

Section 1 General requirements

1.1 Scope

1.1.1 This Section gives the general requirements for hot rolled plates and sections intended for use in the construction of ships, other marine structures, machinery, boilers and pressure vessels.

1.1.2 This Chapter is not applicable to hot rolled bars intended for the manufacture of bolts, plain shafts, etc., by machining operations only. Where used for this purpose, hot rolled bars are to comply with the requirements of Chapter 5.

1.1.3 Plate and strip which is hot coiled after rolling and subsequently uncoiled, cold flattened and cut to the required dimensions are also subject to the appropriate requirements of this Chapter.

1.1.4 Plates, strip, sections and bars are to be manufactured and tested in accordance with the requirements of Chapters 1 and 2, the general requirements of this Section and the appropriate specific requirements given in Sections 2 to 10.

1.1.5 As an alternative to 1.1.4, materials which comply with National or proprietary specifications may be accepted, provided that these specifications give equivalence to the requirements of this Chapter or are approved for a specific application. Particular attention is to be taken of the minimum required under thickness tolerance, *see* 1.6. Generally, survey and certification of such materials are to be carried out in accordance with the requirements of Chapter 1.

1.1.6 Steels intended for high heat input welding above 50 kJ/cm are to be specially approved. Approval will be indicated on the manufacturer's approval certificate by adding a high heat input welding notation to the grade approved, e.g., EH36-W300, indicating approval up to 300 kJ/cm.

1.2 Steel with guaranteed through thickness properties – 'Z' grade steel

1.2.1 When plate material, intended for welded construction, will be subject to significant strains in a direction perpendicular to the rolled surfaces, it is recommended that consideration be given to the use of special plate material with specified through thickness properties, 'Z' grade steel. These strains are usually associated with thermal contraction and restraint during welding, particularly for full penetration 'T'-butt welds, but may also be associated with loads applied in service or during construction. Where these strains are of sufficient magnitude, lamellar tearing may occur. Requirements for 'Z' grade plate material are detailed in Section 8. It is the responsibility of the fabricator to make provision for the use of this material.

1.2.2 Steels intended to have guaranteed through thickness properties will include the supplementary suffix Z25 or Z35 in the designation, for example: LR DH36 Z35.

1.3 Corrosion resistant steels for cargo oil tanks of crude oil tankers

1.3.1 This sub-Section refers to normal and higher strength steels that have approved enhanced corrosion resistance properties intended for application in the internal cargo oil tanks of crude oil tankers.

1.3.2 The additional approval procedures for these steels include specific corrosion tests, *see* Ch 1,2.2.

1.3.3 Normal and higher strength corrosion resistant steels are to be manufactured, tested and certified in accordance with the applicable requirements of Section 2 or Section 3 and the requirements detailed in this sub-Section.

1.3.4 Corrosion resistant steels for cargo oil tanks are primarily intended to apply to steel plates, wide flats and sections up to 50 mm thick and to bars up to 50 mm in diameter.

1.3.5 Corrosion resistant steels for cargo oil tanks are to be identified with one of the following supplementary suffixes, RCU, RCB or RCW in the designation, for example, LR DH36 RCB. These suffixes relate to the area of the tank for which approval testing has been obtained:

RCU, for lower surface of strength deck and surrounding structures;
RCB, for upper surface of inner bottom plating and surrounding structures;
RCW, for both strength deck and inner bottom plating.

1.3.6 Corrosion resistant steels are not to be used in applications other than those specified in 1.3.1.

1.3.7 The weldability of corrosion resistant steels is similar to conventional normal and higher strength steels. Therefore the welding requirements specified in Chapters 11 to 13 are to be adhered with the exception that each corrosion resistant steel is approved with a specified brand of welding consumable and associated welding process.

1.3.8 Each manufacturer's approval certificate for corrosion resistant steels will state the steel grade and area of application designation, specified chemical composition range including additive and/or controlling element percentages to improve corrosion resistance, and brand of welding consumables and welding process used for approval.

1.4 Manufacture

1.4.1 All materials are to be manufactured at works which have been approved by Lloyd's Register (hereinafter referred to as 'LR') for the type and grade of steel which is being supplied and for the relevant steel-making and processing route.

1.4.2 Steel is to be cast in metal ingot moulds or by the continuous casting process. The size of the ingot, billet or slab is to be proportional to the dimensions of the final product such that the reduction ratio is normally to be at least 3 to 1. Sufficient discard is to be taken to ensure soundness in the portion used for further processing.

1.4.3 The cast analysis to be used for certification purposes is to be determined after all alloying additions have been carried out and sufficient time allowed for such an addition to homogenise.

1.4.4 Material may be supplied either as-rolled, normalised, normalising rolled, or thermomechanically controlled rolled. The following definitions apply:

(a) As-rolled (AR) refers to rolling of steel at high temperature followed by air cooling. The rolling and finishing temperatures are typically in the austenite recrystallisation region and above the normalising temperature. The strength and toughness properties of steel produced by this process are generally less than those of steel heat treated, after rolling, or steel produced by advanced processes.

(b) Normalising (N) refers to an additional heating cycle of rolled steel above the critical temperature, A_{c3}, and in the lower end of the austenite recrystallisation region followed by air cooling. The process improves the mechanical properties of as-rolled steel by refining the grain size.

(c) Normalising rolling (NR), also known as controlled rolling, is a rolling procedure in which the final deformation is carried out in the normalising temperature range, resulting in a material condition generally equivalent to that obtained by normalising.

(d) Thermomechanically controlled rolling (TM) is a procedure which involves the strict control of both the steel temperature and the rolling reduction. Generally a high proportion of the rolling reduction is carried out close to the A_{r3} temperature and may involve the rolling in the dual phase temperature region. Unlike normalising rolling the properties conferred by TM (TMCP) cannot be reproduced by subsequent normalising or other heat treatment. The use of accelerated cooling on completion of TM may also be accepted subject to the special approval by LR.

(e) Accelerated Cooling, (AcC) is a process which aims to improve mechanical properties by controlled cooling with rates higher than air cooling immediately after the final TM operation. Direct quenching is excluded from accelerated cooling. The material properties conferred by TM and AcC cannot be reproduced by subsequent normalising or other austenitising heat treatment.

(f) Quenching and Tempering (QT),is a heat treatment process in which steel is heated to an appropriate temperature above the A_{c3} and then cooled with an appropriate coolant for the purpose of hardening the microstructure, followed by tempering, a process in which the steel is re-heated to an appropriate temperature, not higher than the A_{c1} to restore the toughness properties by improving the microstructure.

1.4.5 Where material is being produced by a normalising rolling or a thermomechanically controlled process (T.M.) an additional program of tests for approval is to be carried out under the supervision of the Surveyors and the results are to be to the satisfaction of LR.

1.4.6 Weldable high strength steels may be supplied in the quenched and tempered condition for other marine structures, *see* Section 10.

1.5 Quality of materials

1.5.1 Surface and internal imperfections not prejudicial to the proper application of the steel are not, except by special agreement, to be grounds for rejection. Where necessary, suitable methods of non-destructive examination may be used for the detection of harmful surface and internal defects. The extent of this examination, together with an appropriate acceptance standard, is to be agreed between the purchaser, steelmaker and Surveyor and is to be included in the manufacturing specification.

1.6 Dimensional tolerances

1.6.1 The tolerances on thickness of a given product are defined as:

(a) Minus tolerance is the lower limit of the acceptable range below the nominal thickness.

(b) Plus tolerance is the upper limit of the acceptable range above the nominal thickness.

Nominal thickness is defined by the purchaser at the time of enquiry and order.

1.6.2 The average thickness of a product or products is defined as the arithmetic mean of the measurements made in accordance with the requirements in 1.6.11.

1.6.3 For materials of nominal thickness 5 mm and more intended for hull structural purposes as detailed in Sections 2, 3 and 10, the minus tolerance on thickness of plates, strip and wide flats is 0,3 mm, irrespective of nominal thickness. For wide flats, this applies only where the width is greater than or equal to 600 mm. The average thickness of a product or products is not to be less than the nominal thickness. For thicknesses below 5 mm, the thickness tolerances are to be specially agreed. Plus tolerance is to be in accordance with a National or International Standard.

1.6.4 Class C of ISO 7452 may be applied in lieu of 1.6.3. Where this standard is applied, both the requirements in 1.6.11 and the portion of the footnote of Table B.2 in ISO 7542, that reads; 'Also a minus side of thickness of 0,3 mm is permitted,' are not applicable. Additionally, if ISO 7452 is applied, the steel mill is to ensure that the number of measurements and measurement distribution is appropriate to establish that the plates produced are greater than or equal to the specified nominal thickness.

1.6.5 The minus tolerance on bars and sections (except for wide flats with a width $\geq$ 600 mm) is to be in accordance with the requirements of a recognised National or International Standard.

1.6.6 The Shipbuilder and Owner may agree in individual cases whether they wish to specify a more stringent minus tolerance than that given in this Chapter.

1.6.7 The minus tolerances for plates and wide flats intended for machinery structures are given in Section 5.

1.6.8 For materials intended for applications as detailed in Sections 4 and 6, no minus tolerance is permitted in the thickness of plates and strip. The minus tolerances on sections are to comply with the requirements of a recognised National or International Standard.

1.6.9 For the materials detailed in Section 7, the minus tolerance of material intended for use in the construction of cargo tanks is not to exceed 0,3 mm. For other applications, no minus tolerance is permitted in the thickness of plates and strip.

1.6.10 Dimensional tolerances for material detailed in Section 9 are given in Table 3.9.3.

1.6.11 The average thickness and thickness tolerance is to be measured at locations of a product or products as defined below:

(a) An automated method or manual method may be applied to the thickness measurements. The procedure and the records of measurements are to be made available to the Surveyor and copies provided on request.
(b) At least two lines among Line 1, Line 2 or Line 3, as shown in Fig. 3.1.1, are to be selected for the thickness measurements and at least three points on each selected line as shown in Fig. 3.1.1 are to be selected for thickness measurement on each piece rolled from a single slab or ingot. If more than three points are taken on each line, then the number of points shall be equal on each line.

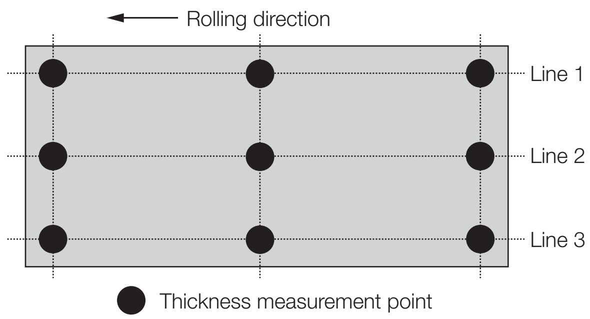


Fig. 3.1.1 Location of thickness measuring points

(c) For automated methods, the measuring points at sides are to be located not less than 10 mm but not greater than 300 mm from the transverse or longitudinal edges of the product.
(d) For manual methods, the measuring points at sides are to be located not less than 10 mm but not greater than 100 mm from the transverse or longitudinal edges of the product.
(e) Additional measurements may be requested by the Surveyor.

1.6.12 Local surface depressions resulting from imperfections and ground areas resulting from the elimination of defects may be disregarded provided that they are in accordance with the requirements of a recognised National or International Standard.

1.6.13 Tolerances relating to length, width, flatness and plus thickness are to comply with a National or International Standard.

1.6.14 The responsibility for maintaining the required tolerances and making the necessary measurements rests with the manufacturer. Occasional checking by the Surveyor does not absolve the manufacturer from this responsibility.

1.6.15 The Shipbuilder is responsible for the storage and maintenance of product(s) delivered with acceptable surface conditions.

1.7 Heat treatment

1.7.1 Acceptable conditions of supply are specified in subsequent Sections of this Chapter.

1.7.2 The manufacturer is to carry out any heat treatment which may be necessary to prevent hydrogen cracking or to make the material in a safe condition for transit. The Surveyor is to be advised of any heat treatment proposed.

1.7.3 Where material is manufactured using a thermo-mechanically controlled process consideration must be given to the possibility of consequent reduction in mechanical properties if it is subjected to heating for forming or stress relieving or is welded using a high heat input.

1.8 Test material and mechanical tests

1.8.1 Depending on the type of product, provision is made in subsequent Sections of this Chapter for the testing of individual items or for batch testing. Where the latter is permitted, all materials in a batch presented for acceptance tests are to be of the same product form, (e.g., plates, flats, sections, etc.), from the same cast and in the same condition of supply.

1.8.2 The test samples are to be fully representative of the material and, where appropriate, are not to be cut from the material until heat treatment has been completed. The test specimens are not to be separately heat treated in any way.

1.8.3 The test material is to be taken from the thickest piece in each batch, *see* Ch 1,4.1.

1.8.4 Test material is to be taken from the following positions:

(a) At the square cut end of plates and flats greater than 600 mm wide, approximately one-quarter width from an edge, *see* Fig. 3.1.2(a).

(b) For flats 600 mm or less in width, bulb flats and other solid sections, at approximately one-third of the width from an edge, *see* Fig. 3.1.2(b), (c) and (d). Alternatively, in the case of channels, beams or bulb angles, at approximately one-quarter of the width from the centreline of the web, *see* Fig. 3.1.2(c).

(c) For rectangular hollow sections, at approximately the centre of any side, *see* Fig. 3.1.2(e). For circular hollow sections, at any position on the periphery.

(d) For bars intended for purposes as detailed in Sections 2, 3, 5 and 9, at approximately one-third of the radius or half-diagonal from the outer surface, *see* Fig. 3.1.2(f). For smaller bars, the position of the test material is to be as close as is possible to the above.

(e) For bars intended for the applications detailed in Sections 4, 6 and 7 at approximately 12,5 mm below the surface. For bars up to 25 mm diameter, the test specimens may be machined coaxially.

(f) For plates and flats with thicknesses in excess of 40 mm, full thickness specimens may be prepared, but when instead a machined round specimen is used then the axis is to be located at a position lying one-quarter of the product thickness from the surface as shown in Fig. 3.1.2(g).

1.8.5 Tensile test specimens and impact test specimens, where required for the type and grade of product being supplied, are to be prepared from each item or batch of material submitted for acceptance.

1.8.6 Where the finished width of plates and flats is greater than 600 mm, the tensile test specimens are to be cut with their principal axes perpendicular to the final direction of rolling. For all other rolled products, the principal axes are to be parallel to the final direction of rolling.

1.8.7 The tensile test specimens are to be machined to the dimensions detailed in Ch 2,2.1.6 and 2.1.7.

1.8.8 Impact test specimens are to be cut with their principal axes either parallel (longitudinal test) or perpendicular (transverse test) to the final direction of rolling, as required by subsequent Sections of this Chapter. Where both longitudinal and transverse impact properties are shown for a particular grade, only the longitudinal test is required to be carried out, unless otherwise specified by the purchase order or subsequent Sections of this Chapter. However, for plates and wide flats, by certifying that the product meets the requirements of the Rules, the manufacturer guarantees that the acceptance values will be met if tested in the transverse direction. The Surveyor may request testing in this direction to confirm conformity.

1.8.9 Impact test specimens are to be of the Charpy V-notch type, machined to the dimensions detailed in Chapter 2. They are to be taken from a position within 2 mm of one of the rolled surfaces, except that for plates and sections over 40 mm thick, the axes of the test specimens are to be at one-quarter of the thickness from one of the rolled surfaces. For bars and other similar products the axes of the test specimens are to be as specified in 1.8.4(d).

1.8.10 Standard test specimens 10 mm square are to be used, except where the thickness of the material does not allow this size of test specimen to be prepared. In such cases the largest possible size of subsidiary test specimen, in accordance with Table 2.3.1 is to be prepared, with the notch cut on the narrow face. Alternatively, for material of suitable thickness, the rolled surfaces may be retained so that the test specimen width will be the full thickness of the material. In such cases the tolerances for width given in Table 2.3.1 in Chapter 2 are not applicable. The notch is to be cut in a face of the test specimen which was originally perpendicular to the rolled surface. The position of the notch is to be not nearer than 25 mm to a flame-cut or sheared edge.

1.8.11 Impact tests are not required when the nominal material thickness is less than 6 mm.

1.8.12 The test procedures used for all tensile and impact tests are to be in accordance with the requirements of Chapter 2.

1.9 Visual and non-destructive examination

1.9.1 Surface inspection and verification of dimensions are the responsibility of the steelmaker and are to be carried out on all material prior to despatch. Acceptance by the Surveyors of material later found to be defective shall not absolve the steelmaker from this responsibility.

1.9.2 With the exception of 'Z' grade plate material (*see* Section 8) and bars for offshore mooring cable (*see* Section 9), the non-destructive examination of materials is not required for acceptance purposes, *see also* 1.5.1. However, manufacturers are expected to employ suitable methods of non-destructive examination for the general maintenance of quality standards.

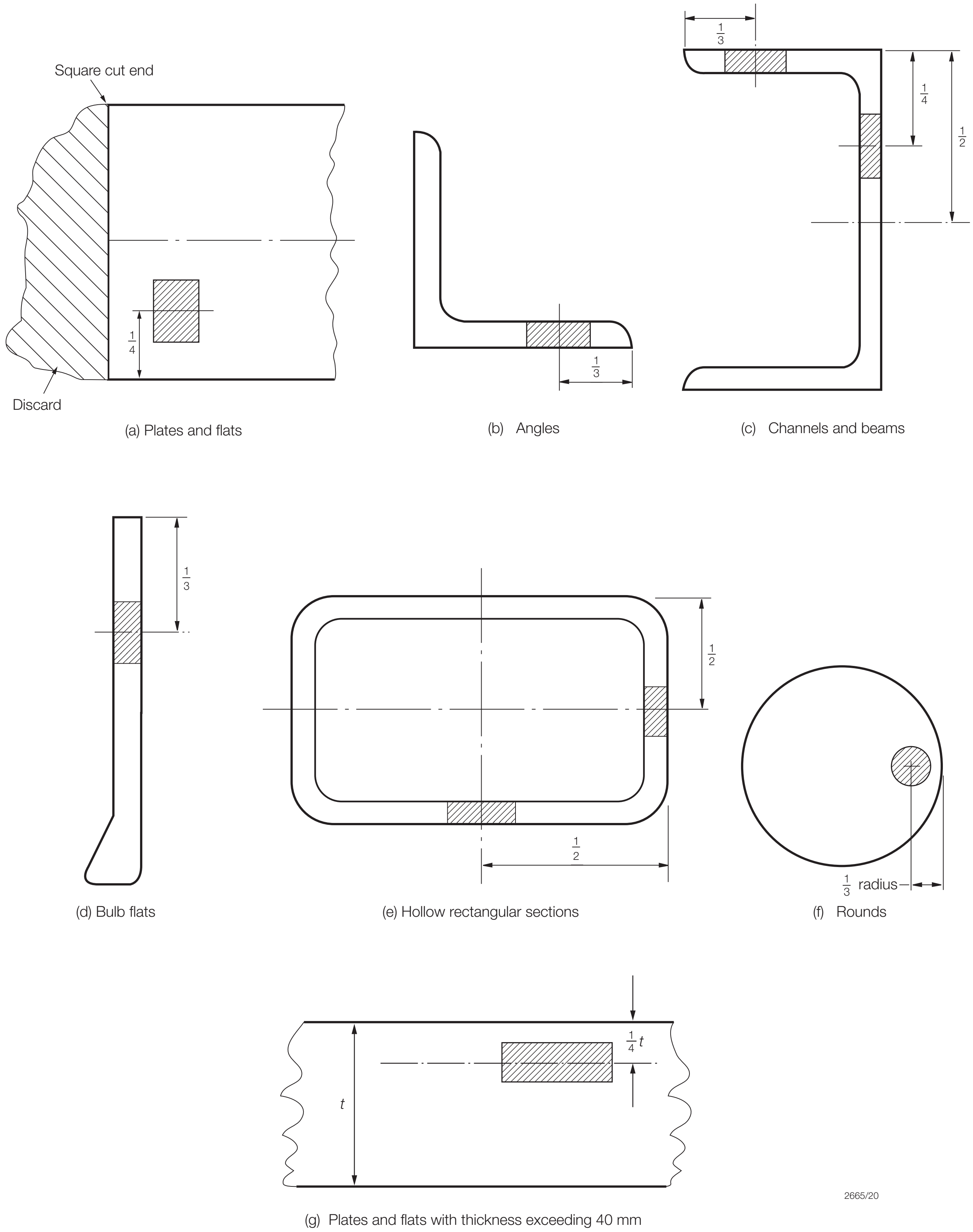


Fig. 3.1.2 Position of test material

1.10 Rectification of defects

1.10.1 For materials intended for structural purposes as detailed in Sections 2, 3 and 5, surface defects may be removed by local grinding provided that:

(a) the thickness is in no place reduced to less than 93 per cent of the nominal thickness, but in no case by more than 3 mm,
(b) each single ground area does not exceed 0,25 m^2,
(c) the total area of local grinding does not exceed two per cent of the total surface,
(d) the ground areas have smooth transitions to the surrounding surface.

Where necessary, the entire surface may be ground to a maximum depth as given by the underthickness tolerances of the product. The extent of such rectification is to be agreed in each case with the Surveyors and is to be carried out under their supervision, unless otherwise agreed. They may request that complete removal of the defect is proven by suitable non-destructive examination of the affected area.

1.10.2 Surface defects which cannot be dealt with as in 1.10.1 may be repaired by chipping or grinding followed by welding, subject to the Surveyor's consent and under his supervision, provided that:

(a) after removal of the defect and before welding, the thickness of the item is in no place reduced by more than 20 per cent,
(b) each single weld does not exceed 0,125 m^2,
(c) the total area of welding does not exceed two per cent of the surface of the side involved,
(d) the distance between any two welds is not less than their average width,
(e) the welds are of reasonable size and made with an excess layer of beads which is then ground smooth to the surface level,
(f) elimination of the defect is proven by suitable non-destructive examination of the affected area,
(g) welding is carried out by an approved procedure and by competent operators using approved electrodes and the repaired area is ground smooth to the correct nominal thickness,
(h) when requested by the Surveyor, the item is normalised or otherwise suitably heat treated after welding and grinding, and
(j) at the discretion of the Surveyor, the repaired area is proven free from defects by suitable non-destructive examination.

1.10.3 For materials intended for applications as detailed in Sections 4, 6 and 7, surface defects may be removed by grinding in accordance with 1.10.1, except that when the thickness is reduced below that given in the approved plans, acceptance will be subject to special consideration. Weld repairs may also be carried out generally in accordance with 1.10.2, except that in all cases suitable heat treatment after welding and non-destructive testing of the repaired areas is required. The fabricator is to be advised regarding the position and extent of all repairs.

1.10.4 For plates which have been produced by a T.M. process or by normalising rolling, repair by welding will be approved by the Surveyor only after procedure tests have shown that the mechanical properties have not been impaired.

1.10.5 Cracks, shells, sand patches and sharp edged seams are always considered defects which would impair the end use of the product and which require rejection or repair irrespective of their size and number. The same applies to other imperfections exceeding the acceptable limits.

1.11 Identification of materials

1.11.1 Every finished item is to be clearly marked by the manufacturer in at least one place with LR's brand and the following particulars:

(a) The manufacturer's name or trade mark.
(b) The grade of steel. The designations given in subsequent Sections of this Chapter may be preceded by the letters 'LR' in order to fully describe the grade, e.g. LR A, LR 490FG. LR LT-FH40, LR 316L, etc.
(c) When the material complies with the requirements of Section 8, the grade is to include the suffix Z25 or Z35, e.g., LR AH36 Z35.
(d) Identification number and/or initials which will enable the full history of the item to be traced.
(e) If required by the purchaser, his order number or other identification mark.

The above particulars, but excluding the manufacturer's name or trade mark where this is embossed on finished products, are to be encircled with paint or otherwise marked so as to be easily recognisable.

1.11.2 Where a number of light materials are securely fastened together in bundles, the manufacturer may brand only the top piece of each bundle or, alternatively, a firmly fastened durable label containing the identification may be attached to each bundle.

1.11.3 In the event of any material bearing LR's brand failing to comply with the test requirements, the brand is to be unmistakably defaced, *see also* Ch 1,4.8.

1.12 Certification of materials

1.12.1 Unless a LR certificate is specified in other parts of the Rules, a manufacturer's certificate validated by LR is to be issued (*see* Ch 1,3.1) and is to include the following particulars:

(a) Purchaser's name and order number.
(b) If known, the contract number for which the material is intended.
(c) Address to which material is dispatched.
(d) Name of steelworks.
(e) Description and dimensions of the material.
(f) Specification or grade of the steel.
(g) Identification number of piece, including test specimen number where appropriate.
(h) Cast number and chemical composition of ladle samples.

(j) Mechanical test results (not required on shipping statements).
(k) Condition of supply.

1.12.2 Before the test certificates are signed by the Surveyor, the steelmaker is required to provide a written declaration stating that the material has been made by an approved process, and that it has been subjected to and has withstood satisfactorily the required tests in the presence of the Surveyor, or an authorised deputy. The following form of declaration will be accepted if stamped or printed on each test certificate with the name of the steelworks and signed by an authorised representative of the manufacturer:

> 'We hereby certify that the material has been made by an approved process and satisfactorily tested in accordance with the Rules of Lloyd's Register'.

1.12.3 When steel is not produced at the works at which it is rolled, a certificate is to be supplied by the steelmaker stating the process of manufacture, the cast number and the chemical composition of ladle samples. The works at which the steel was produced must be approved by LR.

1.12.4 The manufacturer of coiled plate is required to issue a certificate which clearly identifies the material as coil. The certificate issued should include the words; 'Coils covered by this certificate require further processing at a works approved by Lloyd's Register before being certified as plate in accordance with the Rules of Lloyd's Register' in addition to the requirements of 1.12.2.

1.12.5 The supplier of plate cut from coil is required to issue a certificate which clearly identifies the product as finished plate meeting the requirements of the Rules in accordance with 1.12.2.

1.12.6 The form of certificates produced by computer systems is to be agreed with the Surveyor.

■ *Section 2* Normal strength steels for ship and other structural applications

2.1 Scope

2.1.1 The requirements of this Section are primarily intended to apply to steel plates and wide flats not exceeding 100 mm in thickness and sections and bars not exceeding 50 mm in thickness in Grades A, B, D and E. For greater thicknesses, variations in the requirements may be permitted or required for particular applications.

2.1.2 Additional approval tests may be required to verify the suitability for forming and welding of Grade E plate exceeding 50 mm in thickness.

2.2 Manufacture and chemical composition

2.2.1 The method of deoxidation and the chemical composition of ladle samples are to comply with the requirements given in Table 3.2.1.

2.2.2 Small variations from the chemical compositions given in Table 3.2.1 may be allowed for Grade E steel in thicknesses exceeding 50 mm or when any Grade of steel is supplied in a thermo-mechanically controlled processed condition, provided that these variations are documented and approved in advance.

2.2.3 The manufacturer's declared analysis will be accepted subject to occasional checks if required by the Surveyors.

2.2.4 For plate supplied from coil, the chemical analysis can be transposed from the certificate of the coil manufacture onto the re-processor's certificate.

2.3 Condition of supply

2.3.1 All materials are to be supplied in a condition complying with the requirements given in Table 3.2.2. Where alternative conditions are permitted these are at the option of the steelmaker, unless otherwise expressly stated in the order for the material, but a steelmaker is to supply materials only in those conditions for which he has been approved by LR.

2.3.2 Where normalising rolling and thermomechanically controlled rolling (T.M.) processes are used, it is the manufacturer's responsibility to ensure that the programmed rolling schedules are adhered to. Where deviation from the programmed rolling schedule occurs, the manufacturer must ensure that each affected piece is tested and that the local Surveyor is informed.

2.3.3 If a steel product supplied in the T.M. condition is to be subjected to heating for forming or stress relieving or is to be welded by a high energy input process, consideration must be given to the possibility of a consequent reduction in mechanical properties.

2.4 Mechanical tests

2.4.1 The results of all tensile tests and the average energy value from each set of three impact tests are to comply with the appropriate requirements given in Table 3.2.3 except where enhanced by the requirements of this Section.

Table 3.2.1 Chemical composition and deoxidation practice

Grade	A	B	D	E
Deoxidation	For $t \leq 50$ mm: Any method (for rimmed steel, *see* Note 1)	For $t \leq 50$ mm: Any method except rimmed steel	For $t \leq 25$ mm: Killed	Killed and fine grain treated with aluminium
	For $t > 50$ mm: Killed	For $t > 50$ mm: Killed	For $t > 25$ mm: Killed and fine grain treated with aluminium	
Chemical composition % (*see* Note 5)				
Carbon	0,21 max. (*see* Note 2)	0,21 max.	0,21 max.	0,18 max.
Manganese	2,5 x C% min.	0,80 min. (*see* Note 3)	0,60 min.	0,70 min.
Silicon	0,50 max.	0,35 max.	0,10 – 0,35	0,10 – 0,35
Sulphur	0,035 max.	0,035 max.	0,035 max.	0,035 max.
Phosphorus	0,035 max.	0,035 max.	0,035 max.	0,035 max.
Aluminium (acid soluble)	—	—	0,015 min. (*see* Note 4)	0,015 min. (*see* Note 4)
	Carbon + $^{1}/_{6}$ of the manganese content is not to exceed 0,40%			

NOTES
1. For Grade A, rimmed steel may only be accepted for sections up to a maximum thickness of 12,5 mm, provided that it is stated on the test certificates or shipping statements to be rimmed steel.
2. The maximum carbon content for Grade A steel may be increased to 0,23% for sections.
3. Where Grade B is impact tested the minimum manganese content may be reduced to 0,60%.
4. The total aluminium content may be determined instead of the acid soluble content. In such cases the total aluminium content is to be not less than 0,020%.
5. Where additions of any other elements are made as part of the steel-making practice, the content is to be recorded.

Table 3.2.2 Condition of supply

Grade	Thickness, mm	Conditions of supply			
A and B	≤50	Any			(*see* Note 1)
	>50 ≤100	N	NR	TM	(*see* Note 2)
D	≤35	Any			(*see* Note 1)
	>35 ≤100	N	NR	TM	(*see* Note 3)
E	≤100	N		TM	(*see* Note 4)

N = normalised
NR = normalising rolled
TM = thermomechanically controlled-rolled

NOTES
1. 'Any' includes as-rolled, normalised, normalising rolled and thermomechanically controlled-rolled.
2. Plates, wide flats, sections and bars may be supplied in the as-rolled condition, subject to special approval from LR.
3. Sections in Grade D steel may be supplied in thicknesses greater than 35 mm in the as-rolled condition provided that satisfactory results are consistently obtained from Charpy V-notch impact tests.
4. Sections in Grade E steel may be supplied in the as-rolled and normalising rolled conditions provided that satisfactory results are consistently obtained from Charpy V-notch impact tests.

2.4.2 With the exception given in 2.4.4, one tensile test is to be made for each batch presented unless the mass of finished material is greater than 50 tonnes, in which case one test is to be made from a different piece from each 50 tonnes or fraction thereof. Additional tests are to be made for every variation of 10 mm in the thickness or diameter of products from the same cast. For sections, the thickness to be considered is the thickness of the product at the point at which samples are taken for mechanical tests. A piece is to be regarded as the rolled product from a single slab or billet, or from a single ingot if this is rolled directly into plates, strip, sections or bars.

2.4.3 For Grades A and B where plate is supplied from coil, results of the tensile test can be transposed from the certificate of the coil manufacture onto the certificate issued by the re-processor. If the coil mass exceeds 50 tonnes, testing will additionally be required from two locations representing the start and end of the coil. For Grades D and E, the mechanical properties must be sampled from the de-coiled plate in accordance with the frequency specified in the Rules.

2.4.4 For plates of thickness exceeding 50 mm in Grade E steel, one tensile test is to be made on each piece.

Table 3.2.3 Mechanical properties for acceptance purposes

Grade	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on $5,65\sqrt{S_o}$ % minimum	Charpy V-notch impact test (*see* Notes 3, 4, 5, 6 and 7)		
				Thickness mm	Average energy J minimum	
					Longitudinal	Transverse (*see* Note 3)
A B D E	235	400 – 520 (*see* Note 1)	22 (*see* Note 2)	≤50 >50 ≤70 >70 ≤100	27 34 41	20 24 27

Impact tests are to be made on the various grades at the following temperatures:

A grade	not required
B grade	0°C
D grade	–20°C
E grade	–40°C

NOTES
1. For sections in Grade A, the upper limit of the tensile strength range may be exceeded at the discretion of the Surveyor.
2. For full thickness tensile test specimens with a width of 25 mm and a gauge length of 200 mm (*see* Fig. 2.2.4 in Chapter 2), the minimum elongation is to be:

Thickness mm	≤5	>5 ≤10	>10 ≤15	>15 ≤20	>20 ≤25	>25 ≤30	>30 ≤35	>35 ≤50
Elongation %	14	16	17	18	19	20	21	22

3. Tests are to be taken in the longitudinal direction. Normally, transverse test specimens are not required. Transverse test results for plates and wide flats are to be garenteed by the supplier.
4. *See* 2.4.5 and 2.4.6.
5. *See* 2.4.7.
6. *See* 1.8.11.
7. *See* 2.4.14.

2.4.5 For Grade A steel, Charpy V-notch impact tests are not required when the thickness does not exceed 50 mm, or up to 100 mm thick if the material is supplied in either the normalised or thermo-mechanically controlled-rolled condition and has been fine grain treated. However, the manufacturer should confirm, by way of regular in-house checks, that the material will meet a requirement of 27 J at +20°C. The results of these checks shall be reported to the Surveyor. The frequency of these checks should as a minimum be every 250 tonnes.

2.4.6 When Grade A steel is supplied in a thickness greater than 50 mm and either, in the normalising rolled condition, or when special approval has been given to supply in the as-rolled condition, a set of three impact test specimens is to be tested from each batch of 50 tonnes or fraction thereof.

2.4.7 Impact tests are not required for Grade B steel of 25 mm or less in thickness. However, the manufacturer is to confirm, by way of regular in-house tests, and on occasional material selected by the Surveyor, that the material meets the requirement in Table 3.2.3. The results of the tests are to be reported to the Surveyor. The frequency of the in-house checks are to be, as a minimum, one set of three impact test specimens for every 250 tonnes.

2.4.8 For Grade B steels of thicknesses above 25 mm, supplied in the as-rolled or normalising rolled condition, one set of three impact test specimens is to be made from the thickest item in each batch presented. If the mass of finished material is greater than 25 tonnes, one extra set of tests is to be made from a different piece from each 25 tonnes or fraction thereof.

2.4.9 For Grade B steels of thicknesses above 25 mm, supplied in the furnace normalised or thermomechanically controlled-rolled condition, one set of three impact test specimens is to be made from the thickest item in each batch presented. If the mass of finished material is greater than 50 tonnes, one extra set of tests is to be made from a different piece from each 50 tonnes or fraction thereof.

2.4.10 For Grade D steels supplied in the as-rolled or normalising rolled condition, one set of three impact test specimens is to be made from the thickest item in each batch presented. If the mass of finished material is greater than 25 tonnes, one extra set of tests is to be made from a different piece from each 25 tonnes or fraction thereof.

2.4.11 For Grade D steels, supplied in the furnace normalised or thermomechanically controlled-rolled condition, one set of three impact test specimens is to be made from the thickest item in each batch presented. If the mass of finished material is greater than 50 tonnes, one extra set of tests is to be made from a different piece from each 50 tonnes or fraction thereof.

2.4.12 For plates in Grade E steel, one set of three impact test specimens is to be made from each piece. For bars and sections in Grade E steel, one set of three test specimens is to be made from each 25 tonnes or fraction thereof. When, subject to the special approval of LR, sections are supplied in the as-rolled or normalising rolled conditions, one set of impact tests is to be taken from each batch of 15 tonnes or fraction thereof.

2.4.13 The results of all tensile tests and the average energy values from each set of three impact tests are to comply with the appropriate requirements given in Table 3.2.3. For impact tests, one individual value may be less than the required average value provided that it is not less than 70 per cent of this average value. *See* Ch 1,4.6 for re-test procedures.

2.4.14 For batch tested Grade B and D steel plates supplied in a condition other than furnace normalised, with a thickness equal to, or greater than 25 mm and 12 mm respectively, and where the average value of one set of tests is less than 40 J, two further items from the same batch are to be selected and tested. If these fail to achieve an average of 40 J on either set, each individual piece of the heat is to be tested. The plates are acceptable provided they meet the requirements of Table 3.2.3. Additional testing is not required where the manufacturer can demonstrate to the satisfaction of the Surveyor that the plate was rolled outside the limits of the programmed rolling schedule. In this instance the plate should be rejected, *see also* 2.3.2.

2.4.15 Where standard subsidiary Charpy V-notch test specimens are necessary, *see* Ch 2,3.2.4.

2.5 Identification of materials

2.5.1 The particulars detailed in 1.11 are to be marked on all materials which have been accepted. Where a number of light materials are bundled, the bundle is to be identified in accordance with 1.11.2.

2.6 Certification of materials

2.6.1 At least two copies of each test certificate are to be provided. They are to be of the type and give the information detailed in 1.12 and, additionally, are to indicate if sections in Grade A steel of rimming quality have been supplied. As a minimum, the chemical composition is to include the contents of any grain refining elements used and the residual elements, as detailed in Table 3.2.1.

■ *Section 3*
Higher strength steels for ship and other structural applications

3.1 Scope

3.1.1 Provision is made for material to be supplied in four strength levels, 27S, 32, 36 and 40.

3.1.2 Provisions for material supplied in H47 strength grades are specifically intended for hatch comings and deck structure of container ships.

3.1.3 The required notch toughness is designated by subdividing the strength levels into Grades AH, DH, EH and FH.

3.1.4 For the designation to fully identify a steel and its properties the appropriate grade letters should precede the strength level number, e.g. AH32 or FH40.

3.1.5 The requirements of this Section are primarily intended to apply to plates, wide flats, sections and bars not exceeding the thickness limits given in Table 3.3.1. For greater thicknesses, variations in the requirements may be permitted or required for particular applications but a reduction of the required impact energy is not allowed.

Table 3.3.1 Maximum thickness limits

Steel designation				Maximum thickness mm	
				Plates and wide flats	Sections and bars
AH 27S	DH 27S	EH 27S	FH27S	100 (see Note 1)	50
AH 32	DH 32	EH 32	FH32		
AH 36	DH 36	EH 36	FH36		
AH 40	DH 40	EH40	FH40		
AH 47 (*see* Note 2)	DH 47	EH 47	FH 47		Not applicable

NOTES
1. Where the thickness exceeds 50 mm, the steel must initially be approved by way of a Nil Ductility Test, in accordance with ASTM E208, to show adequate crack arrest properties. The Nil Ductility Test Temperature is to be agreed for the thickness approved to ensure the crack arrest temperature is below the minimum design temperature. Where the thickness exceeds 70 mm and the material is used specifically as a crack arrest plate, the material must be specially approved with a crack arrest fracture toughness Kca ≥ 6000 N/mm[1,5].
2. Minimum thickness for H47 strength level is 50 mm, *see* 3.1.2.

3.1.6 It should be noted that the fatigue strength of weldments in steels of high strength levels may not be greater than those of steels of lower strength levels.

3.2 Alternative specifications

3.2.1 Steels differing from the requirements of this Section in respect of chemical composition, deoxidation practice, condition of supply or mechanical properties may be accepted subject to special approval by LR. Such steels are to be given a special designation, *see* 3.7.2.

3.3 Manufacture

3.3.1 All the grades of steel are to be in the killed and fine grain treated condition.

3.4 Chemical composition

3.4.1 The chemical compositions of ladle samples for all grades of steel are to comply with the requirements given in Table 3.3.2. The requirements for H47 strength grade steels are given in Table 3.3.3.

3.4.2 The carbon equivalent is to be calculated from the ladle analysis using the formula given below and is not to exceed the maximum value agreed between the fabricator and the steelmaker when the steel is ordered.

$$\text{Carbon equivalent} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

For TM steels, the agreed carbon equivalent is not to exceed the values given in Table 3.3.4.

3.4.3 The cold cracking susceptibility, P_{cm}, may be used instead of the carbon equivalent for evaluating weldability, in which case the following formula is to be used for calculating the P_{cm} from the ladle analysis:

$$P_{cm} = C + \frac{Si}{30} + \frac{Mn + Cr + Cu}{20} + \frac{Ni}{60} + \frac{Mo}{15} + \frac{V}{10} + 5B$$

The maximum allowable P_{cm} is to be agreed with LR and is to be included in the manufacturing specification and reported on the certificate.

3.4.4 The cold cracking susceptibility, P_{cm}, is to have a maximum value of 0,22 per cent for steels of H47 strength grade.

3.4.5 Small deviations in chemical composition from that given in Table 3.3.2 for plates exceeding 50 mm in thickness in Grades EH36, EH40, FH36 and FH40 may be approved provided that these deviations are documented and approved in advance.

3.4.6 Where the grain refining elements Niobium, Titanium and Vanadium are used either singly or in combination, the chemical composition is to be specifically approved for each Grade in combination with the rolling procedure to be used.

Table 3.3.2 Chemical composition

Grades	AH, DH, EH	FH
Carbon % max.	0,18	0,16
Manganese %	0,9 – 1,60 (*see* Note 1)	0,9 – 1,60
Silicon % max.	0,50	0,50
Phosphorus % max.	0,035	0,025
Sulphur % max.	0,035	0,025
Grain refining elements (*see* Note 2)		
Aluminium (acid soluble) %	0,015 min. (*see* Note 3)	
Niobium %	0,02 – 0,05	
Vanadium %	0,05 – 0,10	
Titanium %	0,02 max.	
Total (Nb + V + Ti) % (*see* Note 5)	0,12 max.	
Residual elements		
Nickel % max.	0,40	0,80
Copper % max.	0,35	0,35
Chromium % max.	0,20	0,20
Molybdenum % max.	0,08	0,08
Nitrogen % max.		0,009 (0,012 max. if Al is present)

NOTES
1. For AH grade steels in all strength levels and thicknesses up to 12,5 mm, the specified minimum manganese content is 0,70%.
2. The steel is to contain aluminium, niobium, vanadium or other suitable grain refining elements, either singly or in any combination. When used singly, the steel is to contain the specified minimum content of the grain refining element. When used in combination, the specified minimum content of each element is not applicable.
3. The total aluminium content may be determined instead of the acid soluble content. In such cases the total aluminium content is to be not less than 0,020%.
4. Alloying elements other than those listed above are to be included in the approved manufacturing specification.
5. The grain refining elements are to be in accordance with the approved specification.

Table 3.3.3 Chemical composition for Grade AH 47, DH 47, EH 47 and FH 47

Chemical element	max. (%)
Carbon	0,20
Manganese	2,00
Silicon	0,55
Phosphorus	0,030
Sulphur	0,030
Nickel	2,00
Chromium	0,25
Molybdenum	0,080
Grain refining elements (*see* Note 1) Aluminium (acid soluble)	0,015 min (*see* Note 2)
Residual elements Copper 0,35	

NOTES
1. The grain refining elements niobium, vanadium and titanium are to be in accordance with the approved specification.
2. The total aluminium content may be determined instead of the acid soluble content. In these cases the total aluminium content is to be not less than 0,020%.

3.4.7 When any grade is supplied in an approved thermomechanically controlled processed condition, variations in the specified chemical composition may be considered, provided that these variations are documented and approved in advance.

3.4.8 For plate supplied from coil, the chemical analysis can be transposed from the certificate of the coil manufacture onto the re-processor's certificate.

3.5 Condition of supply

3.5.1 All materials are to be supplied in a condition complying with the requirements given in Table 3.3.5 or Table 3.3.6. Where alternative conditions are permitted, these are at the option of the steelmaker, unless otherwise expressly stated in the order for the material.

3.5.2 Where normalising rolling and thermomechanically controlled rolling (T.M.) processes are used, it is the manufacturer's responsibility to ensure that the programmed rolling schedules are adhered to. Where deviation from the programmed rolling schedule occurs, the manufacturer must ensure that each affected piece is tested and that the local Surveyor is informed.

3.5.3 The use of precipitation hardening steels is not acceptable, except where such hardening is incidental to the use of grain refining elements.

3.6 Mechanical tests

3.6.1 The results of all tensile tests and the average energy value from each set of three Charpy V-notch impact tests are to comply with the appropriate requirements given in Table 3.3.7 except where enhanced by the requirements of this Section.

3.6.2 For steels in the as-rolled, normalised, normalising rolled or T.M. conditions, one tensile test is to be made for each batch of 50 tonnes or fraction thereof. Additional tests are to be made for every variation of 10 mm in the thickness or diameter of products from the same cast.

3.6.3 Where plate is supplied from coil, both the tensile tests and the Charpy V-notch tests are to be taken from the de-coiled plate in accordance with the frequency specified for the Grade as required by this Section.

3.6.4 For steels in the quenched and tempered condition a tensile test is to be made on each plate as heat treated. For continuously heat treated plates, one tensile test is to be made for each 50 tonnes or fraction thereof from a single cast. Additional tests are to be made for every variation of 10 mm in the thickness of the products from a single cast. The tensile test specimens are to be taken with their axes transverse to the main direction of rolling.

Table 3.3.4 Carbon equivalent requirements for higher tensile strength steels up to 100 mm in thickness when supplied in the TM condition

Grade				Carbon Equivalent, max. (%)	
				$t \leq 50$	$50 < t \leq 100$
AH 27S	DH 27S	EH 27S	FH 27S	0,36	0,38
AH 32	DH 32	EH 32	FH 32	0,36	0,38
AH 36	DH 36	EH 36	FH 36	0,38	0,40
AH 40	DH 40	EH 40	FH 40	0,40	0,42
AH 47	DH 47	EH 47	FH 47	Not applicable (*see* Table 3.3.1)	0,49

NOTE
t = thickness, in mm.

Table 3.3.5 Conditions of supply for plates and wide flats

Grade	Grain refining practice (*see* Note 1)	Thickness range mm	Conditions of supply (*see* Note 2)				
AH 27S AH 32 AH 36	Al or Al + Ti	≤ 20	AR	N	NR	TM	
		>20 ≤ 100	—	N	NR	TM	(*see* Note 3)
	Nb or V or Al + (Nb or V) or Al + (Ti) + (Nb or V)	≤ 12,5	AR	N	NR	TM	
		>12,5 ≤ 100	—	N	NR	TM	
AH 40	Any practice	≤ 12,5	AR	N	NR	TM	
		>12,5 ≤ 50	—	N	NR	TM	
		>50 ≤ 100	—	N	—	TM	QT
DH 27S DH 32 DH 36	Al or Al + Ti	≤ 20	AR	N	NR	TM	
		>20 ≤ 100	—	N	NR	TM	(*see* Note 4)
	Nb or V or Al + (Nb or V) or Al + (Ti) + (Nb or V)	≤ 12,5	AR	N	NR	TM	
		>12,5 ≤ 100	—	N	NR	TM	
DH 40	Any practice	≤ 50	—	N	NR	TM	
		>50 ≤ 100	—	N	—	TM	QT
EH 27S EH 32 EH 36	Any practice	≤ 100	—	N	—	TM	
EH 40	Any practice	≤ 100	—	N	—	TM	QT
FH 27S FH 32 FH 36 FH 40	Any practice	≤ 100	—	N	—	TM	QT
AH 47 DH 47 EH 47 FH 47	Any practice	≤ 50	Not applicable				
		>50 ≤100	TM				

NOTES
1. Grain refining elements used singly or in any combination, require specific approval from Materials and NDE Department, London office.
2. AR = as-rolled N = furnace normalised NR = normalising rolled
TM = thermomechanically controlled-rolled QT = quenched and tempered
3. Material up to 35 mm thick may be supplied in the as-rolled condition provided that prior approval has been obtained from LR.
4. Material up to 25 mm thick may be supplied in the as-rolled condition provided that prior approval has been obtained from LR.

3.6.5 For products in the AH and DH grades, at least one set of three impact tests is to be made on the thickest piece in each batch of 50 tonnes when supplied in either the normalised or thermomechanically controlled condition. When the products are supplied in the as-rolled or normalising rolled conditions a set of impact test specimens is to be taken from a different piece from each 25 tonnes or fraction thereof. When supplied in the quenched and tempered condition, a set of impact tests is to be made on each length as heat treated. Test specimens from the quenched and tempered plates are to have their axes transverse to the main rolling direction.

3.6.6 For plates and wide flats in the EH and FH grades supplied in the normalised or thermomechanically controlled conditions, one set of impact tests is to be made on each piece. For plates supplied in the quenched and tempered condition a set of impact tests is to be made on each length as heat treated. Test specimens from the quenched and tempered plates are to have their axes transverse to the main rolling direction.

3.6.7 For plates and wide flats in H47 strength grade, one set of impact tests is to be made on each piece.

3.6.8 For sections and bars in the EH and FH grades supplied in the normalised or thermomechanically controlled conditions, one set of impact tests is to be made on the thickest piece in a batch not exceeding 25 tonnes. For sections supplied in the as-rolled or normalising rolled conditions the batch size is not to exceed 15 tonnes.

Table 3.3.6 Conditions of supply for sections and bars

Grade	Grain refining practice (*see* Note 1)	Thickness range mm	Conditions of supply (*see* Note 2)			
AH 27S AH 32 AH 36	Al or Al + Ti	≤20	Any			
		>20 ≤50	N	NR	TM	(*see* Note 3)
	Nb or V or Al + Nb or Al + V or Al + (Ti) + (Nb or V)	≤12,5	Any			
		>12,5 ≤50	N	NR	TM	(*see* Note 3)
AH 40	Any practice	≤12,5	Any			
		>12,5 ≤50	N	NR	TM	
DH 27S DH 32 DH 36	Al or Al + Ti	≤20	Any			
		>20 ≤50	N	NR	TM	(*see* Note 3)
	Nb or V or Al + Nb or Al + V or Al + (Ti) + (Nb or V)	≤12,5	Any			
		>12,5 ≤50	N	NR	TM	(*see* Note 3)
DH 40	Any practice	≤50	N	NR	TM	
EH 27S EH 32 EH 36	Any practice	≤50	N	TM		(*see* Notes 3 and 4)
EH 40	Any practice	≤50	N	TM	QT	
FH 27S FH 32 FH 36 FH 40	Any practice	≤50	N	TM	QT	(*see* Note 4)

NOTES
1. Grain refining elements used singly or in any combination require specific approval from Materials and NDE Department, London Office.
2. N = furnace normalised; NR = normalising rolled
   TM = thermomechanically controlled-rolled; QT = quenched and tempered
3. Subject to the special approval of LR, sections may be supplied in the as-rolled condition provided satisfactory results are consistently obtained from Charpy V-notch impact tests.
4. Subject to the special approval of LR, sections may be supplied in the NR condition.

3.6.9 For batch tested plates in a condition other than furnace normalised, with a thickness equal to 12 mm or greater, and where the average value of one set of tests is less than 50 J, two further items from the same batch are to be selected and tested. If these fail to achieve an average of 50 J on either set, each individual piece of the heat is to be tested. The plates are acceptable provided they meet the requirements of Table 3.3.7. Additional testing is not required where the manufacturer can demonstrate to the satisfaction of the Surveyor that the plate was rolled outside the limits of the programmed rolling schedule. In this instance the plate should be rejected, *see also* 3.5.2.

3.6.10 Where standard subsidiary impact specimens are necessary, *see* Ch 2,3.2.4.

3.7 Identification of materials

3.7.1 The particulars detailed in 1.11 are to be marked on all materials which have been accepted and, for ease of recognition, are to be encircled or otherwise marked with paint. Where a number of light products are bundled, the bundle is to be identified in accordance with 1.11.2.

3.7.2 Steels which have been specially approved and which differ from the requirements of this Section are to have the letter 'S' after the agreed identification mark.

3.8 Certification of materials

3.8.1 At least two copies of each test certificate are to be provided. They are to be of the type and give the information detailed in 1.12 and, additionally, are to state the specified maximum carbon equivalent. As a minimum, the chemical composition is to include the contents of any grain refining elements used and of the residual elements.

3.8.2 For steels which have been specially approved, the agreed identification mark, the specified minimum yield stress and, if applicable, the contents of alloying elements are additionally to be stated on the test certificate or shipping statement.

3.8.3 The steelmaker is to provide the Surveyor with a written declaration as detailed in 1.12.2.

Table 3.3.7 Mechanical properties for acceptance purposes (*see* Note 1)

Grades (*see* Note 3)	Yield Stress N/mm^2 min.	Tensile Strength N/mm^2	Elongation on 5,65 $\sqrt{S_o}$ % min. (*see* Note 2)	Charpy V-notch impact tests (*see* Notes 3, 4 and 5) Average energy J minimum					
				$t \leq 50$ mm		$50 < t \leq 70$ mm		$70 < t \leq 100$ mm	
				Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
AH 27S DH 27S EH 27S FH 27S	265	400 – 530	22	27	20	34	24	41	27
AH 32 DH 32 EH 32 FH 32	315	440 – 570	22	31	22	38	26	46	31
AH 36 DH 36 EH 36 FH 36	355	490 – 630	21	34	24	41	27	50	34
AH 40 DH 40 EH 40 FH 40	390	510 – 650	20	39	26	46	31	55	37
AH 47 DH 47 EH 47 FH 47	460	570 – 720	17	–	–	53	35	64	42

Impact tests are to be made on the various grades at the following temperatures:

AH grades 0°C
DH grades –20°C
EH grades –40°C
FH grades –60°C

NOTES

1. The requirements for products thicker than those detailed in the table are subject to agreement, *see* 3.1.4.
2. For full thickness tensile test specimens with a width of 25 mm and a gauge length of 200 mm, *see* Fig. 2.2.4 in Chapter 2, the minimum elongation is to be:

Thickness mm		≤5	>5 ≤10	>10 ≤15	>15 ≤20	>20 ≤25	>25 ≤30	>30 ≤40	>40 ≤50	>50
Elongation %	Strength levels 27S, 32	14	16	17	18	19	20	21	22	To be specially agreed
	Strength level 36	13	15	16	17	18	19	20	21	
	Strength level 40	12	14	15	16	17	18	19	20	

3. Subject to special approval by LR, the minimum tensile strength may be reduced to 470 N/mm^2, for grades AH36, DH36, EH36 and FH36, in the TM condition when micro-alloying elements Nb, Ti or V are used singly and not in combination and provided the yield to tensile strength ratio does not exceed 0,89. For plates with a thickness ≤12 mm, the yield to tensile strength ratio is to be specially considered.
4. Tests are to be taken in the longitudinal direction. Normally, transverse test specimens are not required. Transverse test results for plates and wide flats are to be guaranteed by the supplier.
5. *See* 1.8.11
6. *See* 3.6.9.
7. For steel of H47 strength grade, the yield to tensile strength ratio is not to exceed 0,94.

Section 4
Steels for boilers and pressure vessels

4.1 Scope

4.1.1 Provision is made in this Section for carbon, carbon-manganese and alloy steels intended for use in the construction of boilers and pressure vessels. In addition to specifying mechanical properties at ambient temperature for the purposes of acceptance testing, these requirements also give details of appropriate mechanical properties at elevated temperatures which may be used for design purposes.

4.1.2 Where it is proposed to use a carbon or carbon-manganese steel with a specified minimum tensile strength intermediate to those given in this Section, corresponding minimum values for the yield stress, elongation and mechanical properties at elevated temperatures may be obtained by interpolation.

4.1.3 Carbon and carbon-manganese steels with a specified minimum tensile strength of greater than 490 N/mm^2 but not exceeding 520 N/mm^2 may be accepted, provided that details of the proposed specification are submitted for approval.

4.1.4 Where it is proposed to use alloy steels other than as given in this Section, details of the specification are to be submitted for approval. In such cases the specified minimum tensile strength is not to exceed 600 N/mm^2.

4.1.5 Materials intended for use in the construction of the cargo tanks and process pressure vessels storage tanks for liquefied gases and for other low temperature applications are to comply with the requirements of Section 6 or 7, as appropriate.

4.2 Manufacture and chemical composition

4.2.1 The method of deoxidation and the chemical composition of ladle samples are to comply with the appropriate requirements of Table 3.4.1.

Table 3.4.1 Chemical composition and deoxidation practice

Grade of steel	Deoxidation	Chemical composition %						
Carbon and carbon-manganese steels		C max.	Si	Mn	P	S	Al	Residual elements
360 AR	Any method except rimmed steel	0,18	0,50 max.	0,40 – 1,20	0,040 max.		–	Cr 0,25 max. Cu 0,30 max. Mo 0,10 max. Ni 0,30 max. Total 0,70 max.
410 AR		0,21		0,40 – 1,30			–	
460 AR		0,23		0,80 – 1,50			–	
360	Any method except rimmed steel	0,17	0,35 max.	0,40 – 1,20	0,035 max.		–	
410		0,20		0,50 – 1,30			–	
460		0,20 (*see* Note 1)	0,40 max.	0,80 – 1,40			–	
490	Killed		0,10 – 0,50	0,90 – 1,60			–	
360 FG	Killed fine grained	0,17	0,35 max.	0,40 – 1,20	0,035 max.		(*see* Note 2)	
410 FG		0,20		0,50 – 1,30				
460 FG		0,20 (*see* Note 1)	0,40 max.	0,80 – 1,50				
490 FG			0,10 – 0,50	0,90 – 1,60				
510 FG		0,22						

Alloy steel		C	Si	Mn	P S	Al	Cr	Mo	Residual elements
13Cr Mo 45	Killed	0,10–0,18	0,15–0,35	0,4–0,8	0,035 max.	(*see* Note 3)	0,70–1,30	0,40–0,60	Cu 0,30 max.
11Cr Mo 910		0,08–0,18	0,15–0,50				2,00–2,50	0,90–1,10	Ni 0,30 max.

NOTES
1. For thicknesses greater than 30 mm, carbon 0,22% max.
2. Aluminium (acid soluble) 0,015% min. or
   Aluminium (total) 0,018% min.
   Niobium, vanadium or other suitable grain refining elements may be used either in place of or in addition to aluminium.
3. Aluminium (acid soluble or total) 0,020% max.

4.2.2 For plate supplied from coil, the chemical analysis may be transposed from the certificate of the coil manufacture onto the re-processor's certificate.

4.3 Heat treatment

4.3.1 All materials are to be supplied in a condition complying with the requirements given in Table 3.4.2 except that, when agreed, material intended for hot forming may be supplied in the as-rolled condition.

Table 3.4.2 Condition of supply

Grade of steel	Condition of supply
Carbon and carbon-manganese 360 AR to 460 AR	As-rolled Maximum thickness or diameter is 40 mm
Carbon and carbon-manganese 360 to 490	Normalised or normalised rolled
Carbon and carbon-manganese 360 FG to 510 FG	Normalised or normalised rolled
13Cr Mo 45	Normalised and tempered
11Cr Mo 910	Normalised and tempered

4.4 Mechanical tests

4.4.1 For plates, a tensile test specimen is to be taken from one end of each piece when the mass does not exceed 5 tonnes and the length does not exceed 15 m. When either of these limits is exceeded, tensile test specimens are to be taken from both ends of each piece. A piece is to be regarded as the rolled product from a single slab or from a single ingot if this is rolled directly into plates.

4.4.2 For strip, tensile test specimens are to be taken from both ends of each coil.

4.4.3 Sections and bars are to be presented for acceptance test in batches containing not more than 50 lengths, as supplied. The material in each batch is to be of the same section size, from the same cast and in the same condition of supply. One tensile test specimen is to be taken from material representative of each batch, except that additional tests are to be taken when the mass of a batch exceeds 10 tonnes.

4.4.4 Where plates are required for hot forming and it has been agreed that the heat treatment will be carried out by the fabricator, the tests at the steelworks are to be made on material which has been cut from the plates and given a normalising and tempering heat treatment in a manner simulating the treatment which will be applied to the plates.

4.4.5 If required by the Surveyors or by the fabricator, test material may be given a simulated stress relieving heat treatment prior to the preparation of the test specimens. This has to be stated on the order together with agreed details of the simulated heat treatment and the mechanical properties which can be accepted.

4.4.6 The results of all tensile tests are to comply with the appropriate requirements given in Tables 3.4.3 to 3.4.5.

Table 3.4.3 Mechanical properties for acceptance purposes: carbon and carbon-manganese steels – As-rolled

Grade of steel	Thickness mm	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on $5{,}65\sqrt{S_o}$ % minimum
360 AR	≤ 40	190	360–480	24
410 AR	≤ 40	215	410–530	22
460 AR	≤ 40	240	460–580	21

4.4.7 Where plate is supplied from coil, the tensile tests are to be taken from the de-coiled plate in accordance with the frequency specified for the Grade as required by this Section.

4.4.8 All test specimens are to be taken in the transverse direction unless otherwise agreed.

4.4.9 When material will be subject to strains in a through thickness direction, it is recommended that it should have specified through thickness properties in accordance with the requirements of Section 8.

4.5 Identification of materials

4.5.1 The particulars detailed in 1.11 are to be marked on all materials which have been accepted.

4.6 Certification of materials

4.6.1 At least two copies of each test certificate are to be provided. They are to be of the type and to give the information detailed in 1.12 and, additionally, are to state the specified maximum carbon equivalent. As a minimum, chemical composition is to include the content of any grain refining elements used and of the residual elements, as detailed in Table 3.4.1.

4.7 Mechanical properties for design purposes

4.7.1 Nominal values for the minimum lower yield or 0,2 per cent proof stress at temperatures of 50°C and higher are given in Tables 3.4.6 to 3.4.8.

Table 3.4.4 Mechanical properties for acceptance purposes: carbon and carbon-manganese steels – Normalised or normalised rolled

Grade of steel	Thickness mm (*see* Note)	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on $5,65\sqrt{S_o}$ % minimum
360	>3 ≤16 >16 ≤40 >40 ≤63	205 195 185	360 – 480	26 26 25
410	>3 ≤16 >16 ≤40 >40 ≤63	235 225 215	410 – 530	24 24 23
460	>3 ≤16 >16 ≤40 >40 ≤63	285 255 245	460 – 580	22 22 21
490	>3 ≤16 >16 ≤40 >40 ≤63	305 275 265	490 – 610	21 21 20
360 FG	>3 ≤16 >16 ≤40 >40 ≤63	235 215 195	360 – 480	26 26 25
410 FG	>3 ≤16 >16 ≤40 >40 ≤63	265 245 235	410 – 530	24 24 23
460 FG	>3 ≤16 >16 ≤40 >40 ≤63	295 285 275	460 – 580	22 22 21
490 FG	>3 ≤16 >16 ≤40 >40 ≤63	315 315 305	490 – 610	21 21 21
510 FG	>3 ≤16 >16 ≤40 >40 ≤63	355 345 335	510 – 650	21

NOTE
For thicknesses greater than 63 mm, the minimum values for yield stress may be reduced by 1% for each 5 mm increment in thickness over 63 mm. The minimum elongation values may also be reduced one unit, for all thicknesses over 63 mm. For thicknesses over 100 mm, the above values are to be agreed.

Table 3.4.5 Mechanical properties for acceptance purposes: alloy steels – Normalised and tempered

Grade of steel	Thickness mm (see Note)	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on $5,65\sqrt{S_o}$ % minimum
13Cr Mo45	≤63	305	470–620	20
11Cr Mo910	≤16 >16 ≤63	275 265	480–630	18

NOTE
For thicknesses greater than 63 mm, the minimum values for yield stress may be reduced by 1% for each 5 mm increment in thickness over 63 mm. The minimum elongation values may also be reduced one unit, e.g., for all thicknesses over 63 mm. For thicknesses over 100 mm, the above values are to be agreed.

Table 3.4.6 Mechanical properties for design purposes (*see* 4.7.1) **: carbon and carbon-manganese steels – As-rolled**

Grade of steel	Thickness mm	Design temperature °C (*see* Note)						
		50	100	150	200	250	300	350
		Nominal minimum lower yield or 0,2% proof stress N/mm^2						
360 AR	≤ 40	154	153	152	145	128	108	102
410 AR	≤ 40	186	183	181	174	155	134	127
460 AR	≤ 40	218	213	210	203	182	161	153

NOTE
Maximum permissible design temperature is 350°C.

4.7.2 These values are intended for design purposes only, and verification is not required except for materials complying with National or proprietary specifications where the elevated temperature properties used for design purposes are higher than given in Tables 3.4.6 to 3.4.8.

4.7.3 In such cases, at least one tensile test at the proposed design or other agreed temperature is to be made on material from each cast. Where materials of more than one thickness are supplied from one cast, the thickest material is to be tested. The test specimens are to be prepared from material adjacent to that used for tests at ambient temperature. The axis of the test specimens, is to be between mid and quarter thickness of the material and the test specimens are to be machined to dimensions in accordance with the requirements of Chapter 2. The test procedure is also to be as detailed in Chapter 2, and the results are to comply with the requirements of the National or proprietary specifications.

4.7.4 As an alternative to 4.7.3, a manufacturer may carry out an agreed comprehensive test program for a stated grade of steel to demonstrate that the specified minimum mechanical properties at elevated temperatures can be consistently obtained. This test program is to be carried out under supervision of the Surveyors, and the results submitted for assessment and approval. When a manufacturer is approved on this basis, tensile tests at elevated temperatures are not required for acceptance purposes but, at the discretion of the Surveyors, occasional check tests of this type may be requested.

4.7.5 Values for the estimated average stress to rupture in 100 000 hours are given in Table 3.4.9 and may be used for design purposes.

Table 3.4.7 Mechanical properties for design purposes (*see* 4.7.1)**: carbon and carbon-manganese steels – Normalised or controlled-rolled**

Grade of steel	Thickness mm (*see* Note)	Design temperature °C								
		50	100	150	200	250	300	350	400	450
		Nominal minimum lower yield or 0,2% proof stress N/mm^2								
360	>3 ≤16	183	175	172	168	150	124	117	115	113
	>16 ≤40	173	171	169	162	144	124	117	115	113
	>40 ≤63	166	162	158	152	141	124	117	115	113
410	>3 ≤16	220	211	208	201	180	150	142	138	136
	>16 ≤40	204	201	198	191	171	150	142	138	136
	>40 ≤63	196	192	188	181	168	150	142	138	136
460	>3 ≤16	260	248	243	235	210	176	168	162	158
	>16 ≤40	235	230	227	220	198	176	168	162	158
	>40 ≤63	227	222	218	210	194	176	168	162	158
490	>3 ≤16	280	270	264	255	228	192	183	177	172
	>16 ≤40	255	248	245	237	214	192	183	177	172
	>40 ≤63	245	240	236	227	210	192	183	177	172
360 FG	>3 ≤16	214	204	185	165	145	127	116	110	106
	>16 ≤40	200	196	183	164	145	127	116	110	106
	>40 ≤63	183	179	172	159	145	127	116	110	106
410 FG	>3 ≤16	248	235	216	194	171	152	141	134	130
	>16 ≤40	235	228	213	192	171	152	141	134	130
	>40 ≤63	222	215	204	188	171	152	141	134	130
460 FG	>3 ≤16	276	262	247	223	198	177	167	158	153
	>16 ≤40	271	260	242	220	198	177	167	158	153
	>40 ≤63	262	251	235	217	198	177	167	158	153
490 FG	>3 ≤16	297	284	265	240	213	192	182	173	168
	>16 ≤40	293	279	260	237	213	192	182	173	168
	>40 ≤63	286	272	256	234	213	192	182	173	168
510 FG	>3 ≤63	313	290	270	255	235	215	200	180	—

NOTE
For thicknesses greater than 63 mm, the values for lower yield or 0,2% proof stress are to be reduced by 1% for each 5 mm increment in thickness up to 100 mm. For thicknesses over 100 mm, the values are to be agreed and verified by test.

Table 3.4.8 Mechanical properties for design purposes (*see* 4.7.1)**: alloy steels – Normalised and tempered**

Grade of steel	Thickness mm (see Note)	Design temperature °C									
		50	100	200	300	350	400	450	500	550	600
		Nominal minimum lower yield or 0,2% proof stress N/mm^2									
13CrMo 45	>3 ≤63	284	270	248	216	203	199	194	188	181	174
11CrMo 910	>3 ≤63	255	249	233	219	212	207	194	180	160	137

NOTE
For thicknesses greater than 63 mm, the values for lower yield or 0,2% proof stress are to be reduced by 1% for each 5 mm increment in thickness up to 100 mm. For thicknesses over 100 mm, the values are to be agreed and verified by test.

Table 3.4.9 Mechanical properties for design purposes (*see* 4.7.5)**: estimated average values for stress to rupture in 100 000 hours (units N/mm^2)**

Temperature °C	Grades of steel				
	Carbon and carbon-manganese			Low alloy	
	360FG 410FG 460FG	360 410 460	490 490FG 510FG	13CrMo 45	11CrMo 910
380	171	219	227	—	—
390	155	196	203	—	—
400	141	173	179	—	—
410	127	151	157	—	—
420	114	129	136	—	—
430	102	109	117	—	—
440	90	92	100	—	—
450	78	78	85	290	—
460	67	67	73	262	—
470	57	57	63	235	210
480	47	48	55	208	186
490	36	—	47	181	165
500	—	—	—	155	145
510	—	—	—	129	128
520	—	—	—	103	112
530	—	—	—	80	98
540	—	—	—	62	84
550	—	—	—	49	72
560	—	—	—	42	61
570	—	—	—	36	51
580	—	—	—	—	44

■ *Section 5* Steels for machinery fabrications

5.1 General

5.1.1 Steel plates, sections or bars intended for use in the construction of major components of welded machinery structures, such as bedplates, crankcases, frames and entablatures, are to comply with one of the following alternatives:

(a) Any grade of normal strength structural steel as detailed in Section 2.
(b) Any grade of higher tensile structural steel as detailed in Section 3.
(c) Any grade of carbon-manganese boiler or pressure vessel steel as detailed in Section 4, except that for this application batch testing is acceptable. The size of a batch and the number of tensile tests are to be as detailed in Section 2.

5.1.2 The minus tolerances for products for machinery structures are to be in accordance with Table 3.5.1.

Table 3.5.1 Under thickness tolerances

Nominal thickness, *t* (mm)	Minus tolerance (mm)
$5 \le t < 8$	–0,4
$8 \le t < 15$	–0,5
$15 \le t < 25$	–0,6
$25 \le t < 40$	–0,8
$t \ge 40$	–1,0

5.2 Certification of materials

5.2.1 At least two copies of each test certificate are to be provided. They are to be of the type and give the information detailed in 1.12 and, additionally, are to state the specified maximum carbon equivalent. As a minimum, chemical composition is to include the contents of any grain refining elements used and of the residual elements.

■ *Section 6* Ferritic steels for low temperature service

6.1 Scope

6.1.1 This Section gives specific requirements for carbon-manganese and nickel alloy steels intended for use in the construction of cargo tanks, storage tanks and process pressure vessels for liquefied gases.

6.1.2 The requirements of this Section are also applicable for other types of pressure vessels where the use of steels with guaranteed impact properties at low temperatures is required.

6.1.3 Provision is made for plates and sections up to 40 mm thick.

6.1.4 Steels with alternative chemical compositions or mechanical properties or in a different supply condition may be given special consideration.

6.2 Manufacture and chemical composition

6.2.1 All steels are to be in the killed and fine grain treated condition.

6.2.2 The chemical compositions of carbon-manganese steels are to comply with the appropriate requirements for Grades AH, DH, EH and FH strength levels 27S, 32, 36 and 40, *see* Table 3.3.2. For the uses defined in 6.1.1 and 6.1.2, however, these grades are to be designated LT–AH, LT–DH, LT–EH and LT–FH respectively.

6.2.3 The chemical compositions of nickel alloy steels are to comply with the appropriate requirements of Table 3.6.1.

Table 3.6.1 Chemical compositions of nickel alloy steels

<table>
<tr><th>Grade of steel</th><th>C</th><th>Si</th><th>Mn</th><th>Ni</th><th>P</th><th>S</th><th>Residual elements</th><th>Aluminium</th></tr>
<tr><td>1½ Ni</td><td>0,18 max.</td><td rowspan="4">0,10 – 0,35</td><td>0,30 – 1,50</td><td>1,30 – 1,70</td><td rowspan="4">0,025 max.</td><td rowspan="4">0,020 max.</td><td rowspan="4">Cr 0,25 max.
Cu 0,35 max.
Mo 0,08 max.
Total 0,60 max.</td><td rowspan="4">Total 0,020% min.

Acid soluble 0,015% min.</td></tr>
<tr><td>3½ Ni</td><td>0,15 max.</td><td rowspan="3">0,30 – 0,90</td><td>3,20 – 3,80</td></tr>
<tr><td>5Ni</td><td>0,12 max.</td><td>4,70 – 5,30</td></tr>
<tr><td>9Ni</td><td>0,10 max.</td><td>8,50 – 10,0</td></tr>
</table>

6.2.4 For plate supplied from coil, the chemical analysis may be transposed from the certificate of the coil manufacture onto the re-processor's certificate.

6.3 Heat treatment

6.3.1 All materials are to be supplied in a condition complying with the requirements given in Table 3.6.2.

Table 3.6.2 Supply conditions

<table>
<tr><th>Grade</th><th>Plates</th><th>Sections and bars</th></tr>
<tr><td>LT – AH</td><td rowspan="2">N TM</td><td rowspan="3">Any</td></tr>
<tr><td>LT – DH</td></tr>
<tr><td>LT – EH</td><td rowspan="2">Normalised (see Note)
T.M.C.P.
Quenched and tempered</td></tr>
<tr><td>LT – FH</td><td>N TM</td></tr>
<tr><td>1½ Ni
3½ Ni
5Ni</td><td colspan="2">Normalised (see Note)
Normalised and tempered
Quenched and tempered</td></tr>
<tr><td>9Ni</td><td colspan="2">Double normalised and tempered
Quenched and tempered</td></tr>
<tr><td colspan="3">NOTE
Where the term 'Normalised' is used it does not include normalising rolling.</td></tr>
</table>

6.4 Mechanical tests

6.4.1 For plates, tensile test specimens are to be taken from both ends of each piece. A piece is to be regarded as the rolled product from a single slab or from a single ingot if this is rolled directly into plates.

6.4.2 For strips, tensile test specimens are to be taken from both ends of each coil.

6.4.3 Sections and bars are to be presented for acceptance test in batches containing not more than 50 lengths, as supplied. The material in each batch is to be of the same section size, from the same cast and in the same condition of supply. One tensile test specimen is to be taken from material representative of each batch, except that additional tests are to be taken when the mass of a batch exceeds 10 tonnes.

6.4.4 One set of three Charpy V-notch impact test specimens is to be taken for each tensile test specimen required.

6.4.5 For plates, these impact test specimens are to be cut with the principal axis perpendicular to the final direction of rolling. For sections, the impact test specimens are to be taken longitudinally.

6.4.6 The results of all tensile tests are to comply with the appropriate requirements given in Table 3.6.3. The ratio between the yield stress and the tensile strength is not to exceed 0,9 for normalised and TM steels and 0,94 for QT steels.

6.4.7 The average value for the three impact tests is to comply with the appropriate requirements given in Table 3.6.3. One individual value may be less than the required value provided that it is not less than 70 per cent of this average value. *See* Ch 2,1.4 for re-test procedures.

6.4.8 Where standard subsidiary impact specimens are necessary, *see* Ch 2,3.2.4.

6.4.9 Where plate is supplied from coil, both the tensile tests and the Charpy V-notch tests are to be taken from the de-coiled plate in accordance with the frequency specified for the Grade as required by this Section.

6.5 Identification of materials

6.5.1 The particulars detailed in 1.11 are to be marked on all materials which have been accepted.

Table 3.6.3 Mechanical properties for acceptance purposes (*see* Note 1)

Grade of steel		Yield stress N/mm² min.	Tensile strength N/mm²	Elongation on 5,65 $\sqrt{S_o}$ % min.	Charpy V-notch impact tests (*see* Note 3) Test temp. °C	Impact energy
LT – AH	27S	265	400 – 530	22	0	Plates – transverse tests Average energy 27 J min Sections and bars – longitudinal tests Average energy 41 J min
	32	315	440 – 590	22		
	36	355	490 – 620	21		
	40	390	510 – 650	20		
LT – DH	27S	265	400 – 530	22	–20	
	32	315	440 – 590	22		
	36	355	490 – 620	21		
	40	390	510 – 650	20		
LT – EH	27S	265	400 – 530	22	–40	
	32	315	440 – 590	22		
	36	355	490 – 620	21		
	40	390	510 – 650	20		
LT – FH	27S	265	400 – 530	22	–60	
	32	315	440 – 590	22		
	36	355	490 – 620	21		
	40	390	510 – 650	20		
1½ Ni		275	490 – 640	22	–65	
3½ Ni		285	450 – 610	21	–95	
5Ni		390	540 – 740	21	–110	
9Ni		490	640 – 790	18	–196	

NOTES
1. These requirements are applicable to products not exceeding 40 mm in thickness. The requirements for thicker products are subject to agreement.
2. The minimum design temperatures at which plates of different thicknesses in the above grades may be used are given in Fig. 3.6.1 and Fig. 3.6.2. Consideration will be given to the use of thicknesses greater than those in the Tables or to the use of design temperatures below –165°C.
3. Impact tests are not required on thicknesses less than 6 mm.

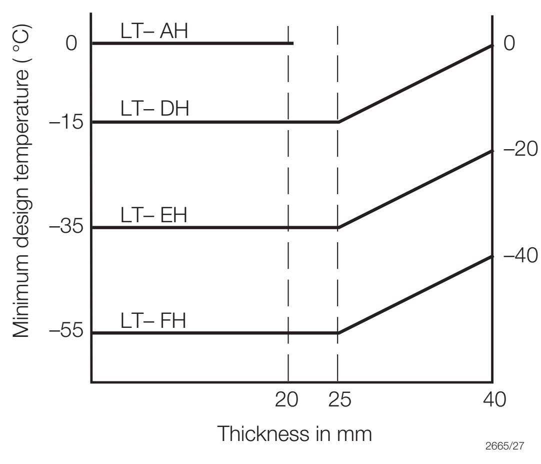


Fig. 3.6.1
Minimum design temperatures for carbon-manganese grades

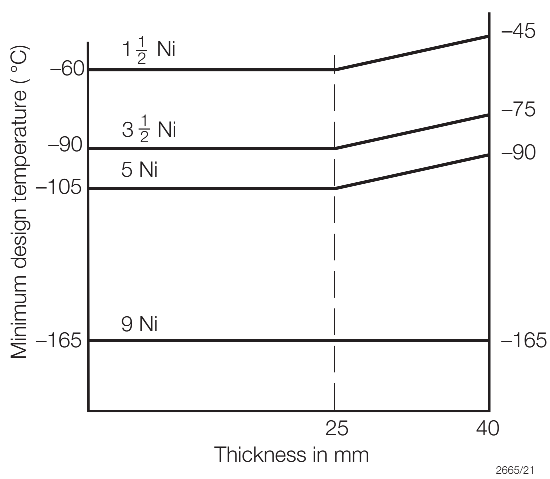


Fig. 3.6.2
Minimum design temperatures for nickel grades

6.6 Certification of materials

6.6.1 At least two copies of each test certificate are to be provided. They are to be of the type and give the information detailed in 1.12 together with general details of the heat treatment. As a minimum, chemical composition is to include the contents of any grain refining elements used and of the residual elements as detailed in Tables 3.3.2 or 3.6.1.

Section 7 Austenitic and duplex stainless steels

7.1 Scope

7.1.1 Provision is made in this Section for rolled products in austenitic and duplex (austenite plus ferrite) stainless steels intended for use in the construction of cargo tanks, storage tanks and process pressure vessels for chemicals and liquefied gases.

7.1.2 Austenitic stainless steels are suitable for applications where the lowest design temperature is not lower than –165°C.

7.1.3 Austenitic stainless steels are also suitable for service at elevated temperatures, and for such applications the proposed specification should contain, in addition to the requirements of 7.1.6, minimum values for 0,2 and 1,0 per cent proof stresses at the design temperature.

7.1.4 Duplex stainless steels are suitable for applications where the lowest design temperature is above 0°C. Any requirement to use duplex stainless steels below 0°C will be subject to special consideration.

7.1.5 Duplex stainless steels are also suitable for service at temperatures up to 300°C, and for such applications the proposed specification should include, in addition to the requirements of 7.1.6, a minimum value for 0,2 per cent proof stress at the design temperature.

7.1.6 A specification giving details of the chemical composition, heat treatment and mechanical properties, including, for the austenitic grades, both the 0,2 and 1,0 per cent proof stresses, is to be submitted for consideration and approval.

7.2 Chemical composition

7.2.1 The chemical composition of ladle samples is to comply with the requirements given in Table 3.7.1.

7.2.2 Consideration will be given to the use of steels whose compositions are outside the scope of Table 3.7.1.

7.3 Heat treatment

7.3.1 All materials are to be supplied in the solution treated condition.

Table 3.7.1 Chemical composition

Type and grade of steel	Chemical composition % (*see* Note)									
	C	Si	Mn	P	S	Cr	Ni	Mo	N	Other
Austenitic										
304 L	0,03	1,0	2,0	0,045	0,03	17,0—20,0	8,0—13,0	—	0,10	—
304 LN	0,03	1,0	2,0	0,045	0,03	17,0—20,0	8,0—12,0	—	0,10—0,22	—
316 L	0,03	1,0	2,0	0,045	0,03	16,0—18,5	10,0—15,0	2,0—3,0	0,10	—
316 LN	0,03	1,0	2,0	0,045	0,03	16,0—18,5	10,0—14,5	2,0—3,0	0,10—0,22	—
317 L	0,03	1,0	2,0	0,045	0,03	18,0—20,0	11,0—15,0	3,0—4,0	0,10	—
317 LN	0,03	1,0	2,0	0,045	0,03	18,0—20,0	12,5—15,0	3,0—4,0	0,10—0,22	—
321	0,08	1,0	2,0	0,045	0,03	17,0—19,0	9,0—12,0	—	0,10	5 x C ≤ Ti ≤ 0,7
347	0,08	1,0	2,0	0,045	0,03	17,0—19,0	9,0—13,0	—	0,10	10 x C ≤ Nb ≤ 1,0
Duplex										
UNS S 31803	0,03	1,0	2,0	0,03	0,02	21,0—23,0	4,5—6,5	2,5—3,5	0,08—0,20	—
UNS S 32750	0,03	0,80	1,2	0,035	0,02	24,0—26,0	6,0—8,0	3,0—5,0	0,24—0,32	Cu 0,50 max.

NOTE
All figures are a maximum value except where a range is shown.

Table 3.7.2 Mechanical properties for acceptance purposes

Type and grade of steel	0,2% Proof stress (N/mm^2) minimum	1% Proof stress (N/mm^2) minimum	Tensile strength (N/mm^2) minimum	Elongation on $5,65\sqrt{S_o}$ % minimum
Austenitic				
304L	170	210	485	40
304LN	205	245	515	40
316L	170	210	485	40
316LN	205	245	515	40
317L	205	245	515	40
317LN	240	280	550	40
321	205	245	515	40
347	205	245	515	40
Duplex				
UNS S 31803	450	—	620	25
UNS S 32750	550	—	795	15

7.4 Mechanical tests

7.4.1 Tensile test specimens are to be taken in accordance with the appropriate requirements of 4.4 and 6.4.1.

7.4.2 For the duplex grades, one set of three Charpy V-notch impact test specimens machined from the longitudinal direction for each tensile test is to be tested at –20°C. The average energy value of the three specimens is to be not less than 41 Joules.

7.4.3 Unless otherwise agreed, impact tests are not required from the austenitic grades of steel given in this Section.

7.4.4 Where standard subsidiary Charpy V-notch test specimens are necessary, *see* Ch 2,3.2.4.

7.4.5 The results of all tensile tests are to comply with the requirements of Table 3.7.2 or the approved specification.

7.5 Metallographic examination for sigma phase

7.5.1 The microstructure of all grades listed in Table 3.7.1 are to be examined metallographically at x400 magnification to demonstrate that sigma phase remains below 0,1 per cent of the observable area at a frequency of one per heat.

7.6 Intergranular corrosion tests

7.6.1 For certain specific applications such as storage tanks for chemicals, it may be necessary to demonstrate that the material used is not susceptible to intergranular corrosion resulting from grain boundary precipitation of chromium-rich carbides.

7.6.2 When required, one test of this type is to be carried out for each tensile test. The material for the test is to be taken adjacent to that for the tensile test.

7.6.3 Unless otherwise agreed or required for a particular chemical cargo, the testing procedure is to be as given in 7.6.4, *see* Ch 2,9.

7.6.4 Wherever practical, exposed cut edges should be avoided. However, where any such edges are to remain after fabrication is completed, it is to be shown by an appropriate test, that the corrosion resistance is adequate for the cargoes expected to be encountered.

7.7 Clad plates

7.7.1 Carbon or carbon-manganese steel plates, clad on one or both surfaces with a suitable grade of austenitic or duplex stainless steel, may be used for the construction of cargo or storage tanks for chemicals.

7.7.2 The carbon or carbon-manganese steel base plates are to comply with the requirements of Section 4, and the austenitic cladding material generally with the requirements of this Section.

7.7.3 The process of manufacture is to be specially approved and may be either by roll cladding, or by explosive bonding.

7.7.4 Where the use of clad materials is proposed, the material specification is to be submitted for consideration, together with details of the extent, and the acceptance standards for non-destructive examination.

7.8 Identification of materials

7.8.1 The particulars detailed in 1.11 are to be marked on all materials which have been accepted.

7.9 Certification of materials

7.9.1 At least two copies of each test certificate are to be provided. They are to be of the type and give the information detailed in 1.12 and, where applicable, the results obtained from intercrystalline corrosion tests, and, additionally, are to state the specified maximum carbon equivalent. As a minimum, chemical composition is to include the contents of any grain refining elements used and of the residual elements, as detailed in Table 3.7.1.

Section 8
Plates with specified through thickness properties

8.1 Scope

8.1.1 Provision is made in this Section for 'Z' grade plate and wide flat material with improved ductility in the through thickness or 'Z' direction, *see* Fig. 3.8.1. The use of this material is recommended for certain types of welded structures (*see* 1.2) in order to minimise the possibility of lamellar tearing either during fabrication or erection.

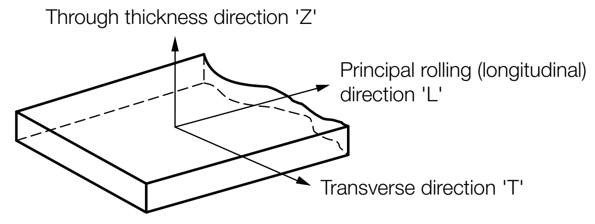


Fig. 3.8.1 Schematic of testing directions

8.1.2 Through thickness properties are characterised by specified values for reduction of area in a through thickness tensile test.

8.1.3 Provision is made for two grades Z25 and Z35. For normal ship applications the Z25 grade is applicable, whilst the Z35 grade is for more severe applications.

8.1.4 This 'Z' grade material is to comply with the requirements of Sections 2, 3, 4, 5 and 6 as appropriate, and the additional requirements of this Section.

8.1.5 The test procedure detailed in this Section may also be used to demonstrate that no unacceptable amount of banding of any detrimental phase, such as sigma is present, *see* 7.5.

8.2 Manufacture

8.2.1 All plates and wide flats are to be manufactured at works, which have been approved by LR for this quality of material.

8.2.2 It is recommended that the steel should be efficiently vacuum de-gassed. The sulphur content is not to exceed 0,008 per cent.

8.2.3 Consideration will be given to proposals for alternative methods of improving through thickness properties.

8.3 Test material

8.3.1 Unless otherwise agreed, through thickness tensile tests are only required for plate materials where the thickness exceeds 15 mm for carbon and alloy steels, or 10 mm in the case of austenitic and duplex stainless steels.

8.3.2 For plates and wide flats, one test sample is to be taken close to the longitudinal centreline from one end of each rolled piece representing the batch, *see* Table 3.8.1 and Fig. 3.8.2. The test sample must be large enough to accommodate the preparation of 6 specimens. 3 test specimens are to be prepared while the rest of the sample remains for possible retest.

Table 3.8.1 Batch size dependent on product and sulphur content

Product	$S > 0{,}005\%$	$S \leq 0{,}005\%$
Plates	Each piece (parent plate)	Maximum 50 *t* of products of the same cast, thickness and heat treatment
Wide flats of nominal thickness ≤ 25 mm	Maximum 10 *t* of products of the same cast, thickness and heat treatment	Maximum 50 *t* of products of the same cast, thickness and heat treatment
Wide flats of nominal thickness > 25 mm	Maximum 20 *t* of products of the same cast, thickness and heat treatment	Maximum 50 *t* of products of the same cast, thickness and heat treatment

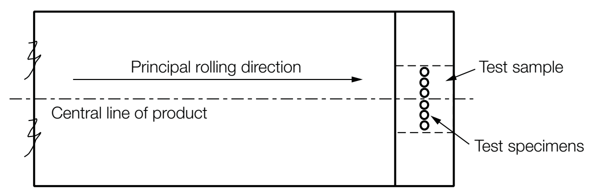


Fig. 3.8.2
Plate and wide flat sampling position

8.3.3 The dimensions of the test specimens are to be in accordance with Ch 2,2.1.12.

8.3.4 Alternatively, test sampling may be carried out in accordance with an accepted National or International Standard.

8.4 Mechanical tests

8.4.1 The three through thickness tensile test specimens are to be tested at ambient temperature, and for acceptance are to give a minimum average reduction of area value of not less than that shown in Table 3.8.2. Only one individual value may be below the minimum average, but should not be less than the minimum individual value shown for the appropriate grade.

Table 3.8.2 Reduction of area acceptance values

Grade	Z25	Z35
Minimum average	25%	35%
Minimum individual	15%	25%

8.4.2 If the average value fails to comply with 8.4.1, three additional tests may be made on specimens from the same test sample. The results of these tests are to be added to those previously obtained to form a new average, which for acceptance is to be not less than 25 per cent for grade Z25 or 35 per cent for grade Z35. No individual results in the re-test shall be below 25 per cent for grade Z25 or 35 per cent for grade Z35, *see* Fig. 3.8.3.

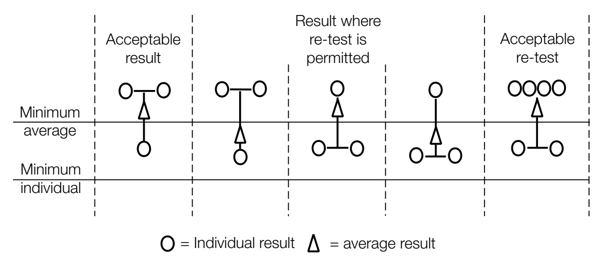


Fig. 3.8.3
Diagram showing acceptance/rejection and re-test criteria

8.4.3 Where batch testing is permitted, and failure after re-test occurs, the tested piece is to be rejected. Each remaining piece in the batch may be individually tested and accepted, based on satisfactory results.

8.4.4 If the fracture of a test specimen occurs in the weld or in the heat affected zone the test is to be regarded as invalid and is to be repeated on a new test specimen.

8.5 Non-destructive examination

8.5.1 All 'Z' grade plates are to be ultrasonically tested in the final supply condition with a probe frequency of 3-5 MHz. The testing is to be performed in accordance with and in compliance with either EN 10160 Level S1/E1 or ASTM A 578 Level C.

8.6 Identification of materials

8.6.1 Products which comply with the requirements of this Section are to have the notation Z25 or Z35 added to the steel grade designation.

8.7 Certification of materials

8.7.1 The following information is required to be included on the certificate in addition to the appropriate steel grade requirements:
(a) Through thickness reduction in area (%), individual results and average.
(b) Steel grade with Z25 or Z35 notation.

8.7.2 Steel grade requirements are to comply with Sections 1 to 7.

■ *Section 9*
Bars for welded chain cables

9.1 Scope

9.1.1 Provision is made in this Section for rolled steel bars intended for the manufacture of three Grades (U1, U2 and U3) of stud link chain cable for the anchoring and mooring of ships and five Grades (R3, R3S, R4, R4S and R5) of offshore mooring cable.

9.1.2 For the ship grades, U1, U2 and U3, approval will permit the supply of bars of the appropriate grades and size to any chain cable manufacturer.

9.1.3 For the offshore grades, R3, R3S, R4, R4S and R5, approval is confined to bar to be supplied to a nominated chain manufacturer and will be given only after successful testing of a completed chain. Separate approvals are required if bar is to be supplied to more than one cable manufacturer. Approval of a higher grade does not cover approval of a lower grade, as all grades must be individually approved.

9.1.4 For all grades, approval is normally given for diameters of bars no greater than those of the bars used in procedure tests.

9.2 Manufacture

9.2.1 All grades of bar material are to be made from killed steel, and all grades of bar material except for Grade U1 chain cables are to be fine grained. For Grades R4S and R5 the austenite grain size is to be 6 or finer, in accordance with ASTM E112.

9.2.2 The bars are to be made to a specification approved by LR which should include the manufacturing procedure, deoxidation practice, heat treatment and mechanical properties.

9.2.3 The rolling reduction ratio of bars for Grades R3, R3S, R4, R4S and R5 must be at least 5:1.

9.3 Chemical composition

9.3.1 For Grades U1, U2 and U3 the chemical composition should be generally within the limits given in Table 3.9.1.

9.3.2 For Grades R3, R3S, R4, R4S and R5 the chemical composition is to comply with an approved specification, *see* 9.2.2.

9.3.3 For Grades R4, R4S and R5 chain cable the steel should contain a minimum of 0,2 per cent molybdenum. The reported composition is to include the contents of antimony, arsenic, tin, copper, nitrogen, aluminium and titanium.

9.3.4 For Grades R4S and R5 the steel used must be vacuum degassed.

9.4 Heat treatment

9.4.1 Unless stipulated otherwise, the bars are to be supplied in the as-rolled condition, but the supplier is to be advised by the chain manufacturer of the heat treatment to be used for the completed chain in order that the mechanical test specimens may be tested in the condition of heat treatment used for the chain.

9.4.2 For Grades U1 and U2, the samples selected from each batch may be tested either in the as-rolled condition, or after heat treatment where the chain is to be used in the heat treated condition, in full cross-section and in a manner simulating the heat treatment applied to the finished cable.

9.4.3 For Grades U3, R3, R3S, R4, R4S and R5 the sample is to be tested after heat treatment as detailed in 9.4.2.

9.5 Embrittlement tests

9.5.1 For Grades R3, R3S, R4, R4S and R5 the bar manufacturer is to provide evidence that the material is not susceptible to strain ageing, or to temper brittleness under the conditions of manufacture of the chain. The results of the relevant tests are to be reported to LR at the approval stage. Approval will be restricted to the specified steel composition and if later this is altered then re-approval will be required. Temper brittleness testing may be waived, if the chain is to be quenched after tempering.

9.5.2 Each heat of steel bars of grades R3S, R4, R4S and R5 is to be tested for hydrogen embrittlement (*see* Ch 2,5.3). In the case of continuous casting, test samples representing both the beginning and the end of the heat are to be taken. In the case of ingot casting, test samples representing two different ingots are to be taken.

9.5.3 Each sample is to be heat treated in a manner simulating the heat treatment of the finished chain. From each sample, two specimens are to be prepared from the mid-diameter of the bar and tested in accordance with Ch 2,5.3.

9.5.4 The ratio Z_1/Z_2 is to be greater than or equal to 0,85, where Z_1 is the reduction in area without baking and Z_2 the reduction in area after baking.

9.5.5 If the requirement is not met, the material is to be subjected to a hydrogen degassing treatment which is subject to approval by LR. Further tests are to be performed after degassing.

9.6 Mechanical tests

9.6.1 Bars of the same nominal diameter are to be presented for test in batches of 50 tonnes or fraction thereof from the same cast. A suitable length from one bar in each batch is to be selected for test purposes. Test pieces are to be taken from the positions as shown in Fig. 3.9.1.

9.6.2 For all grades, one tensile test is to be taken from each sample length selected. Additionally, for Grades U3, R3, R3S, R4, R4S and R5 material, one set of three Charpy V-notch impact test specimens is to be prepared. Impact tests are also required for Grade U2 when the chain is to be supplied in as-welded condition.

Table 3.9.1 Chemical composition of killed steel bars

Grade	Chemical composition %												
	C max.	Si	Mn	P max.	S max.	Al	Nb max.	V max.	N max.	Cr max.	Cu max.	Ni max.	Mo max.
U1	0,20	0,15–0,35	0,40 min.	0,04	0,04	–	–	–	–	–	–	–	–
U2	0,24	0,15–0,55	1,60 max.	0,035	0,035	0,02 min. *see* Note 1	–	–	–	–	–	–	–
U3	0,33	0,15–0,35	1,90 max.	0,04	0,04	0,065 max. *see* Note 2	0,05 *see* Note 2	0,10 *see* Note 2	0,015	0,25	0,35	0,40	0,08

NOTES
1. Aluminium may be partly replaced by other grain refining elements.
2. To obtain fine grain steel, at least one of these grain refining elements must be present in sufficient amount.

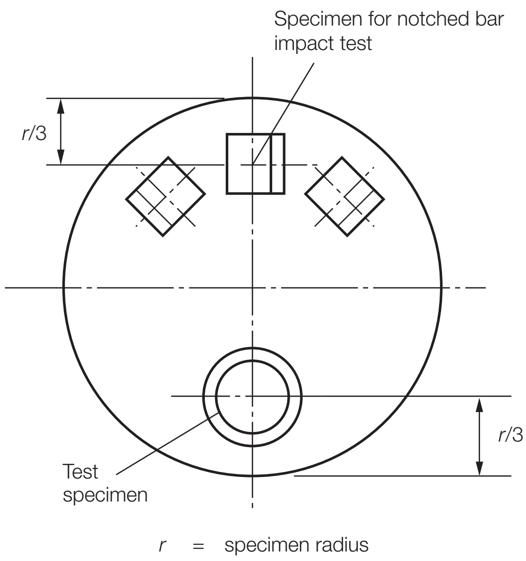


Fig. 3.9.1 Sampling of steel bars

9.6.3 The results of all tensile and, where applicable, impact tests are to be in accordance with the appropriate requirements of Table 3.9.2.

9.6.4 Failure to meet the requirements will result in the rejection of a batch of material, unless it is clearly attributed to improper simulated heat treatment. This is to be confirmed to be to the satisfaction of LR, and further heat treatment and testing will be required prior to acceptance.

9.7 Structure and hardenability tests

9.7.1 For Grades R4S and R5, the following tests are to be carried out on each heat:

(a) Assessment and quantification of the level of non-metallic micro inclusion. These must be acceptable for the final product.

(b) Macro etching on a representative sample, in accordance with ASTM E381 or equivalent. This must be free from any injurious segregation or porosity.

(c) Jominy hardenability tests in accordance with ASTM A255 or equivalent.

9.8 Dimensional tolerances

9.8.1 The tolerances on diameter and ovality of the bar are to be in accordance with Table 3.9.3.

Table 3.9.2 Mechanical properties

Grade	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on 5,65 $\sqrt{S_o}$ % minimum	Reduction of area % minimum	Charpy V-notch impact tests		
					Test temperature °C	Average energy J minimum	Average energy flash weld J minimum
U1	–	370–490	25	—	—	—	—
U2	295	490–690	22	—	0 (*see* Note 1)	27	—
U3	410	690 minimum	17	40	0 –20 (*see* Note 2)	60 35	— —
R3	410 (*see* Note 3)	690 minimum (*see* Note 3)	17	50	0 –20 (*see* Note 2)	60 40	50 30
R3S	490 (*see* Note 3)	770 minimum (*see* Note 3)	15	50	0 –20 (*see* Note 2)	65 45	53 33
R4	580 (*see* Note 3)	860 minimum (*see* Note 3)	12	50	–20	50	36
Grade R4S (*see* Note 4)	700 (*see* Note 3)	960 minimum (*see* Note 3)	12	50	–20	56	40
Grade R5 (*see* Note 4)	760 (*see* Note 3)	1000 minimum (*see* Note 3)	12	50	–20	58	42

NOTES
1. Impact tests may be waived when the chain cable is to be supplied in one of the heat treated conditions given in Table 10.2.3.
2. Testing may be carried out at either 0°C or –20°C, at the option of LR.
3. The ratio of yield strength to tensile strength should not exceed 0,92.
4. The maximum hardness for R4S is to be HB330, and for R5 is to be HB340.

Table 3.9.3 Dimensional tolerance of bar stock

Nominal diameter mm	Tolerance on diameter mm	Tolerance on roundness ($d_{max} - d_{min}$) mm
≤20	–0/+1,0	0,60
>20 ≤25	–0/+1,0	0,60
>26 ≤35	–0/+1,2	0,80
>36 ≤50	–0/+1,6	1,10
>51 ≤80	–0/+2,0	1,50
>81 ≤100	–0/+2,6	1,95
>101 ≤120	–0/+3,0	2,25
>121 ≤160	–0/+4,0	3,00
>161 ≤210	–0/+5,0	4,00

9.9 Non-destructive examination

9.9.1 For the R3, R3S, R4, R4S and R5 grades all bars are to be inspected by a magnetic particle or eddy current method, and are also to be subjected to ultrasonic examination.

9.9.2 All non-destructive examination is to be carried out in accordance with approved procedures, in accordance with Ch 1,5.

9.9.3 All non-destructive examination operators are to be qualified in the method of non-destructive examination, to a minimum of Level II in accordance with a recognised standard.

9.9.4 The bars are to be free from pipes, cracks, flakes, and injurious surface defects such as seams, laps, and rolled-in mill scale. Longitudinal discontinuities may be removed by blending to a smooth contour provided that their depth is not greater than 1 per cent of the bar diameter, and that the required diameter tolerances are not compromised. The contour radiuses are to be a minimum of four times the excavation depth.

9.9.5 The frequency of non-destructive testing may be reduced at the discretion of LR, provided statistical evidence is available that the required quality is achieved consistently.

9.10 Identification

9.10.1 Each bar is to be identified in accordance with 1.10 and, in addition, is to be marked with the appropriate grade of chain cable.

9.11 Certification of materials

9.11.1 Each consignment of bars is to be accompanied by a certificate of a type and in accordance with 1.12, but with the addition of the grade of chain cable, the rolling reduction ratio, the results of the micro inclusion, macro etch and hard-enability tests, where required by each grade.

■ *Section 10*
High strength quenched and tempered steels for welded structures

10.1 Scope

10.1.1 Provision is made in this Section for weldable high strength quenched and tempered steel plates and wide flats up to 70 mm thick. However, special consideration will be given to thicknesses up to 50 mm supplied in the TM rolled condition.

10.1.2 Plates and wide flats exceeding 70 mm in thickness as well as other product forms may also be supplied in accordance with the requirements of this Section, provided that the prior agreement of LR is obtained.

10.1.3 The steels may be supplied in six strength levels with minimum yield stresses of 420, 460, 500, 550, 620 and 690 N/mm^2 respectively.

10.1.4 Each strength level is sub-divided into four grades AH, DH, EH and FH, differing essentially in the required levels of notch toughness.

10.1.5 For the designation to fully identify a steel and its properties, the appropriate grade letter should precede the strength level number, e.g., EH 42.

10.1.6 Steels differing in strength level, mechanical properties and chemical composition from those detailed in this Section may be supplied, subject to special approval from LR. Such steels are to have the letter 'S' after the agreed identification mark.

10.2 Manufacture and chemical composition

10.2.1 The steels are to be fully killed and fine grain treated.

10.2.2 The chemical composition is to comply with the requirements of the approved manufacturing specification and the limits set in Table 3.10.1.

Table 3.10.1 Chemical composition

Grade	AH	DH EH	FH
Carbon % max	0,21	0,20	0,18
Manganese % max	1,70	1,70	1,60
Silicon % max	0,55	0,55	0,55
Phosphorus % max	0,035	0,030	0,025
Sulphur % max	0,035	0,030	0,025
Nitrogen % max	0,020	0,020	0,020
Grain refining elements (*see* Note 1)			
Aluminium (acid soluble) % min (*see* Note 2)		0,015	
Niobium %		0,02—0,05	
Vanadium %		0,03—0,10	
Titanium % max		0,02	
Total (Nb + V + Ti) % max		0,12	

NOTES
1. The steel is to contain aluminium, niobium, vanadium or other suitable grain refining elements, either singly or in any combination. When used singly, the content is to be within the limits given in the Table. When used in combination, these limits are not applicable but the proportions of the grain refining elements are to be in accordance with the approved manufacturing specification.
2. The total aluminium content may be determined instead of the acid soluble content. In such cases the total aluminium content is not to be less than 0,020%.
3. Alloying elements and residual elements other than those listed in the Table (e.g., Ni, Cr, Cu, Mo and B) are to be included in the approved manufacturing specification.

10.2.3 The cold cracking susceptibility, P_{cm}, may be used as an alternative to the carbon equivalent for evaluating weldability. It is to be calculated from the ladle analysis using the following formula:

$$P_{cm} = C + \frac{Si}{30} + \frac{Mn + Cr + Cu}{20} + \frac{Ni}{60} + \frac{Mo}{15} + \frac{V}{10} + 5B$$

The maximum allowable P_{cm} is to be agreed with LR and is to be included in the approved manufacturing specification.

10.3 Mechanical properties

10.3.1 At least one tensile test piece and one set of three Charpy V-notch impact tests specimens are to be taken from each piece as heat treated.

10.3.2 For continuously heat treated products, one tensile test piece and a set of three impact test specimens are to be taken from each plate as heat treated.

10.3.3 For plates and wide flats with widths exceeding 600 mm, the tensile and impact test specimens are to be taken with their axes transverse to the final direction of rolling. For other products, the impact test specimens are to be taken in the longitudinal direction but the tensile test specimens may be taken in either the longitudinal or transverse direction as agreed with LR.

10.3.4 The results of all tests are to comply with the appropriate requirements of Table 3.10.2.

10.3.5 Where standard subsidiary impact test specimens are necessary, *see* Ch 2,3.2.4.

10.4 Identification of materials

10.4.1 The particulars detailed in 1.11 are to be marked on each piece which has been accepted and, for ease of recognition, are to be encircled or otherwise marked with paint.

10.5 Certification of materials

10.5.1 At least two copies of each test certificate are to be provided. They are to be of the type and give the information detailed in 1.12 and, additionally, are to state the specified maximum carbon equivalent. As a minimum, chemical composition is to include the contents of any grain refining elements used and of the residual elements as detailed in Table 3.10.1.

Table 3.10.2 Mechanical properties for acceptance purposes

Grade	Yield stress N/mm^2 min. (*see* Note 1)	Tensile strength N/mm^2	Elongation on $5{,}65\sqrt{S_o}$ % minimum (*see* Note 2)		Charpy V-notch impact tests (*see* Note 4)		
					Test temperature	Average energy J minimum	
			Transverse	Longitudinal	°C	Transverse	Longitudinal
AH 42 DH 42 EH 42 FH 42	420	530 – 680	18	20	0 –20 –40 –60	28	42
AH 46 DH 46 EH 46 FH 46	460	570 – 720	17	19	0 –20 –40 –60	31	46
AH 50 DH 50 EH 50 FH 50	500	610 – 770	16	18	0 –20 –40 –60	33	50
AH 55 DH 55 EH 55 FH 55	550	670 – 830	16	18	0 –20 –40 –60	37	55
AH 62 DH 62 EH 62 FH 62	620	720 – 890	15	17	0 –20 –40 –60	41	62
AH 69 DH 69 EH 69 FH 69	690	770 – 940	14	16	0 –20 –40 –60	46	69

NOTES
1. Where a distinct yield stress indication is not obtainable during tensile testing the 0,2% proof stress is applicable.
2. For full thickness tensile test specimens with a width of 25 mm and a gauge length of 200 mm (*see* Fig. 2.2.4 in Chapter 2) the minimum elongation is to be:

Thickness mm		≤10	>10 ≤15	>15 ≤20	>20 ≤25	>25 ≤40	>40 ≤50	>50 ≤70
Strength levels								
Elongation %	42	11	13	14	15	16	17	18
	46	11	12	13	14	15	16	17
	50 and 55	10	11	12	13	14	16	16
	62	9	11	12	12	13	14	15
	69	9	10	11	11	12	13	14

These values apply to transverse specimens. Where the use of longitudinal specimens has been agreed, the values are to be increased by 2%.
3. The ratio of yield strength to tensile strength should not exceed 0,94.
4. Impact tests are not required on thicknesses less than 6 mm.

Steel Castings

■ *Section 1* General requirements

1.1 Scope

1.1.1 This Section gives the general requirements for steel castings intended for use in the construction of ships, other marine structures, machinery, boilers, pressure vessels and piping systems.

1.1.2 Where required by the relevant Rules dealing with design and construction, castings are to be manufactured and tested in accordance with Chapters 1 and 2, together with the general requirements given in this Section and the appropriate specific requirements given in Sections 2 to 9.

1.1.3 As an alternative to 1.1.2, castings which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Chapter or alternatively are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

1.1.4 Where small castings are produced in large quantities, or where castings of the same type are produced in regular quantities, alternative survey procedures, in accordance with Ch 1,2.4 may be adopted.

1.2 Manufacture

1.2.1 Castings are to be made at foundries approved by LR. The steel used is to be manufactured by a process approved by Lloyd's Register (hereinafter referred to as 'LR').

1.2.2 All flame cutting, scarfing or arc-air gouging to remove surplus metal is to be undertaken in accordance with recognised good practice and is to be carried out before the final heat treatment. Preheating is to be employed where necessitated by the chemical composition and/or thickness of the casting. The affected areas are to be either machined or ground smooth for a depth of about 2 mm unless it has been shown that the material has not been damaged by the cutting process. Special examination will be required to find any cracking in way of the cut surfaces.

1.2.3 Where two or more castings are joined by welding to form a composite item, details of the proposed welding procedure are to be submitted for approval. Welding approval procedure tests will be required, *see also* the requirements of 1.9.

1.3 Quality of castings

1.3.1 All castings are to be free from surface or internal defects which would be prejudicial to their proper application in service. The surface finish is to be in accordance with good practice and any specific requirements of the approved specification.

1.3.2 The surfaces are not to be hammered, peened or treated in any way which may obscure defects.

1.3.3 The locations of all chaplets are to be noted and to be subject to close visual inspection (and when necessary ultrasonic examination) to ensure complete fusion.

1.4 Chemical composition

1.4.1 All castings are to be made from killed steel. The chemical composition of the ladle sample is to be within the limits given in the relevant Section of this Chapter. Where general overall limits are specified, the chemical composition is to be appropriate for the type of steel, dimensions and required mechanical properties of the castings.

1.4.2 Except where otherwise specified, suitable grain refining elements may be used at the discretion of the manufacturer. The content of such elements is to be reported in the ladle analysis.

1.5 Heat treatment

1.5.1 All castings are to be heat treated in accordance with the requirements given in the relevant Section of this Chapter.

1.5.2 Heat treatment is to be carried out in a properly constructed furnace which is efficiently maintained and has adequate means of temperature control. The furnace dimensions are to be such as to allow the steel castings to be uniformly heated to the necessary temperature. Sufficient thermocouples are to be connected to the steel castings to show that their temperature is adequately uniform and the temperatures are to be recorded throughout the heat treatment. Alternative procedures are to be approved by LR, Materials and NDE department. Copies of these records are to be presented to the Surveyor together with a sketch showing the positions at which the temperature measurements were carried out. The records are to identify the furnace that was used and give details of the individual steel castings, the heat treatment temperature and time at temperature and the date. The Surveyor is to examine the charts and confirm the details on the certificate. In the case of very large components which require heat treatment, alternative methods will be specially considered.

1.5.3 If a casting is locally reheated, or any straightening operation is performed after the final heat treatment, a subsequent stress relieving heat treatment may be required in order to avoid the possibility of harmful residual stresses.

1.6 Test material and test specimens

1.6.1 Test material sufficient for the tests specified in Sections 2 to 9 and for possible re-test purposes is to be provided for each casting. The test samples are to be either integrally cast or gated to the casting and are to have a thickness of not less than 30 mm.

1.6.2 The test samples are not to be detached from the casting until the heat treatment specified in 1.5.1 has been completed and they have been properly identified.

1.6.3 As an alternative to 1.6.1 and 1.6.2, where a number of small castings of about the same size, each of which is under 1000 kg in mass, are made from one cast and heat treated in the same furnace charge, a batch testing procedure may be adopted, using separately cast test samples of suitable dimensions. The test samples are to be properly identified and heat treated together with the castings which they represent. At least one test sample is to be provided for each batch of castings.

1.6.4 The test specimens are to be prepared in accordance with the requirements of Chapter 2. Tensile test specimens are to have a cross-sectional area of not less than 150 mm^2.

1.6.5 Re-test procedures are to be in accordance with Ch 2,1.4.

1.7 Visual and non-destructive examination

1.7.1 This Section gives the general requirements for non-destructive examination of steel castings. As an alternative, castings may be examined in accordance with a National Specification, provided it gives reasonable equivalence to these Rules.

1.7.2 All castings are to be cleaned and adequately prepared for inspection. Suitable methods include pickling, caustic cleaning, wire brushing, local grinding, shot or sand blasting.

1.7.3 The surfaces are not to be hammered, peened or treated in any way which may obscure defects.

1.7.4 Unless otherwise agreed, the accuracy and verification of dimensions are the responsibility of the manufacturer.

1.7.5 All castings are to be presented to the Surveyor for visual examination. Where applicable, this is to include the examination of internal surfaces. Castings are to be subject to magnetic particle examination or dye penetrant inspection (for austenitic stainless steel castings, *see* Section 8) in accordance with 1.7.9, unless more specific requirements for non-destructive examination are included in subsequent Sections of this Chapter, other parts of the Rules or the agreed specification.

1.7.6 Where specified or required by the Rules non-destructive examination is to be carried out before acceptance. All tests are to be in accordance with the requirements of Ch 1,5.

1.7.7 The manufacturer is to provide the Surveyor with a signed report confirming that non-destructive examination has been carried out and that such inspection has not revealed any significant defects.

1.7.8 Where magnetic particle examination is specified or required, this is to be carried out using a suspension of magnetic particles in a suitable fluid. The dry powder method is not acceptable for the final inspection. Prods are not permitted on finished machined surfaces.

1.7.9 Where required, magnetic particle or dye penetrant testing is to be carried out by the manufacturer whenever appropriate and also when the castings are in the finished condition. The tests are to be made in the presence of the Surveyor unless otherwise specially agreed. The castings are to be examined in the following areas:

(a) At all accessible fillets and changes of section.
(b) At positions where surplus metal has been removed by flame cutting, scarfing or arc-air gouging.
(c) In way of fabrication weld preparations, for a distance not less than 50 mm form the edge.
(d) In way of welds.
(e) In way of chaplets.
(f) At other positions agreed with the Surveyor to include areas which may be subjected to high stress in service.

1.7.10 Where required by subsequent Sections or by the agreed specification, ultrasonic examination is to be carried out by the manufacturer, but Surveyors may request to be present in order to verify that the examination is carried out in accordance with the agreed procedure. This examination is to be carried out in the following areas:

(a) At positions which may be subjected to high stresses in service, as agreed with the Surveyor.
(b) In way of fabrication weld preparations, for a distance not less than 50 mm form the edge.

(c) At positions where subsequent machining may expose filamentary shrinkage or other defects (e.g., bolt holes, bearing bores).
(d) In way of welding.
(e) In way of riser positions.
(f) At positions where experience shows that significant internal defects may occur: these are to be agreed between the manufacturer and the Surveyor.

1.7.11 Radiographic examination, where required, is to be carried out by the manufacturer in areas generally as indicated for ultrasonic examination in 1.7.10. All radiographs are to be submitted to the Surveyor for examination and acceptance. The radiographic technique and acceptance standards are to be to the satisfaction of the Surveyor and in accordance with any requirements of the approved specification.

1.7.12 In the event of any casting proving to be defective during subsequent machining or testing it is to be rejected notwithstanding any previous certification.

1.7.13 The general acceptance criteria given in 2.5.2 are to be applied where no specific acceptance criteria are stated in the subsequent Sections of this Chapter.

1.8 Pressure testing

1.8.1 Where required by the relevant Rules, castings are to be pressure tested in the final machined condition before final acceptance. These tests are to be carried out in the presence of the Surveyors and are to be to their satisfaction.

1.9 Rectification and dressing of castings

1.9.1 When unacceptable defects are found in a casting, these are to be removed by machining or chipping. Flame-scarfing or arc-air gouging may also be used provided that preheating is employed when necessary and that the surfaces of the resulting excavation are subsequently ground smooth. Complete elimination of the defective material is to be proven by adequate non-destructive examination. Shallow grooves or excavations resulting from the removal of defects may, at the discretion of the Surveyor, be accepted provided that they will cause no appreciable reduction in the strength of the castings and that they are suitably blended by grinding. Complete elimination of the defective material is to be verified by magnetic particle or dye penetrant testing.

1.9.2 Where flame scarfing or arc-air gouging is used, the requirements detailed in 1.2.2 are to apply.

1.9.3 Grinding wheels for use on austenitic stainless steels are to be of an iron-free type and shall have been used only on stainless steels.

1.9.4 All proposals to repair a defective casting by welding are to be submitted to the Surveyor before this work is commenced. The Surveyor is to satisfy himself that the number, position and size of the defects are such that the casting can be effectively repaired.

1.9.5 A statement and/or sketch detailing the extent and position of all welds is to be prepared by the manufacturer. Copies of these sketches are to be submitted to LR, and copies are to be attached to the certificates for the castings.

1.9.6 All welding is to be carried out by an approved welder and in accordance with an approved welding procedure which includes the features referred to in 1.9.6 to 1.9.13.

1.9.7 Where welding is required, a grain refining heat treatment is to be given to the whole casting prior to carrying out welding unless agreed otherwise with the Surveyor. Grain refining heat treatment requires heating above the upper critical temperature.

1.9.8 Any excavations are to be of suitable shape to allow good access for welding and, after final preparation for welding, are to be re-examined by suitable non-destructive testing methods to ensure that all defective material has been eliminated.

1.9.9 All castings in alloy steels other than austenitic and duplex stainless steels are to be suitably preheated prior to welding. Castings in carbon-manganese steels may also be required to be preheated, depending on their chemical composition, the dimensions, configuration and positions of the welds.

1.9.10 Welding is to be carried out under cover, in positions free from draughts and adverse weather conditions. As far as possible, all welding is to be carried out in the downhand (flat) position.

1.9.11 The welding consumables used are to be of an appropriate composition, giving a weld deposit with mechanical properties similar and in no way inferior to those of the parent castings. The use of low hydrogen type welding consumables is preferred. Welding procedure tests are to be carried out by the manufacturer to demonstrate that satisfactory mechanical properties can be obtained after heat treatment as detailed in 1.9.12, and the results of these tests are to be presented to the Surveyor.

1.9.12 After welding is completed, the castings are to be given the heat treatment specified in Sections 2 to 9, or a stress relieving heat treatment at a temperature of not less than 550°C. The type of heat treatment required will be dependent on the chemical composition of the casting and the dimensions, positions and nature of the repairs.

1.9.13 Special consideration may be given to a local stress relieving heat treatment. where both the welded area is small and machining of the casting has reached an advanced stage, prior agreement is to be obtained from LR in writing. The welding procedure is to be such that residual stresses are minimised.

1.9.14 On completion of heat treatment, all welds and adjacent material are to be ground smooth and examined by magnetic particle, or liquid penetrant testing, ultrasonic or radiographic examination. The Surveyor is to attend at these inspections, to witness the results of magnetic particle or liquid penetrant examination and to examine any radiographs. Satisfactory results are to be obtained from all forms of non-destructive examination used.The acceptance criteria for the NDE of welds are to be in accordance with subsequent Sections of this Chapter or where these do not exist, Tables 13.2.4 to 13.2.6 in Chapter 13, as appropriate.

1.9.15 Where no welding has been made on a casting, the manufacturer is to provide the Surveyor with a written statement that this is the case.

1.9.16 The foundry is to maintain full records detailing the weld procedure, heat treatment and the extent and location of all welds made to each casting. These records are to be available for review by the Surveyor, and copies of individual records are to be supplied to the Surveyor on request.

1.9.17 For rectification of defective steel castings for crankshafts, *see* 4.7.

1.10 Identification of castings

1.10.1 The manufacturer is to adopt a system of identification, which will enable all finished castings to be traced to the original cast, and the Surveyor is to be given full facilities to trace the castings when required.

1.10.2 Before acceptance, all castings which have been tested and inspected with satisfactory results are to be clearly marked by the manufacturer with the following particulars:

(a) Identification number, cast number or other marking which will enable the full history of the casting to be traced.
(b) Manufacturer's name or trade mark.
(c) LR or Lloyd's Register and the abbreviated name of LR's local office.
(d) Personal stamp of Surveyor responsible for inspection.
(e) Test pressure, where applicable.
(f) Date of final inspection.

1.10.3 Where small castings are manufactured in large numbers, modified arrangements for identification may be specially agreed with the Surveyor.

1.11 Certification of materials

1.11.1 A LR certificate is to be issued, *see* Ch 1,3.1.

1.11.2 The manufacturer is to provide the Surveyor with a written statement giving the following particulars for each casting or batch of castings which has been accepted:

(a) Purchaser's name and order number.
(b) Description of castings and steel grade.
(c) Identification number.
(d) Steel-making process, cast number, chemical analysis of ladle samples and, in the case of the Special grade (*see* Section 2), the chemical analysis of the product or test bar.
(e) General details of heat treatment including the temperature and time at temperature.
(f) Results of mechanical tests.
(g) Test pressure, where applicable.

1.11.3 Where applicable, the manufacturer is to provide a signed report regarding non-destructive examination as required by 1.7.7 together with a statement and/or sketch detailing the extent and position of all weld repairs made to each casting as required by 1.9.5 or the statement detailed in 1.9.15.

■ *Section 2* Castings for ship and other structural applications

2.1 Scope

2.1.1 The requirements for carbon-manganese steel castings, intended for ship and other structural applications where the design and acceptance tests are related to mechanical properties at ambient temperature, are given in this Section.

2.1.2 Provision is made for two quality grades, Normal and Special.

2.1.3 Where it is proposed to use carbon-manganese steels of higher specified minimum tensile strength than required by 2.4.3, or alloy steels, particulars of the chemical composition, mechanical properties and heat treatment are to be submitted for approval.

2.2 Chemical composition

2.2.1 The chemical composition of ladle samples is to comply with Table 4.2.1.

2.2.2 For the Special grade, the product of the aluminium and nitrogen contents is to comply with the following formula:

$$(\%\ Al_{acid\ sol}\ x\ \%\ N)\ 10^5 \leq 60$$

2.2.3 For the Special grade, a check chemical analysis on the product or a test bar is mandatory. The check analysis on the product or test bar is to comply with the requirements of Table 4.2.1.

Table 4.2.1 Chemical composition

Quality grade	Normal	Special (*see* Note 3)
Carbon	0,23% max.	0,23% max.
Silicon	0,60% max.	0,60% max.
Manganese	0,70–1,60%	0,70–1,60%
Sulphur	0,040% max.	0,035% max.
Phosphorus	0,040% max.	0,035% max.
Aluminium – (acid soluble)	—	0,015–0,080% (*see* Notes 1 and 2)
Residual elements:		
Copper	0,30% max.	0,30% max.
Chromium	0,30% max.	0,30% max.
Nickel	0,40% max.	0,40% max.
Molybdenum	0,15% max.	0,15% max.
Total	0,80% max.	0,80% max.

NOTES
1. The total aluminium content may be determined instead of the acid soluble content, in which case the total aluminium content is to be 0,020–0,10%.
2. Grain refining elements other than aluminium may be used subject to special agreement with LR.
3. For the Special grade, the nitrogen content is to be determined.

2.3 Heat treatment

2.3.1 Castings are to be supplied:
(a) fully annealed; or
(b) normalised; or
(c) normalised and tempered at a temperature of not less than 550°C; or
(d) quenched and tempered at a temperature of not less than 550°C.

2.3.2 For larger castings where a coarse of microstructure may be present in heavier thickness, a double austenising heat treatment may be required to ensure adequate grain refinement. A coarse microstructure will be indicated by an increased attenuation of approxiamtely 30 dB/m at 2 MHz during ultrasonic examination.

2.3.3 Following weld repair and or the attachment of handling brackets, all castings are to be subject to post weld heat treatment at a temperature of not less than 550°C before delivery.

2.4 Mechanical tests

2.4.1 At least one tensile test is to be made on material representing each casting or batch of castings.

2.4.2 Where the casting is of complex design, or where the finished mass exceeds 10 tonnes, two test samples are to be provided. Where large castings are made from two or more casts which are not mixed in a ladle prior to pouring, two or more test samples are required corresponding to the number of casts involved. These are to be integrally cast at locations as widely separated as possible.

2.4.3 The results of these tests are to comply with the following requirements:

Yield stress	200 N/mm^2 min.
Tensile strength	400 N/mm^2 min.
Elongation on $5{,}65\sqrt{S_o}$	25% min.
Reduction of area	40% min.

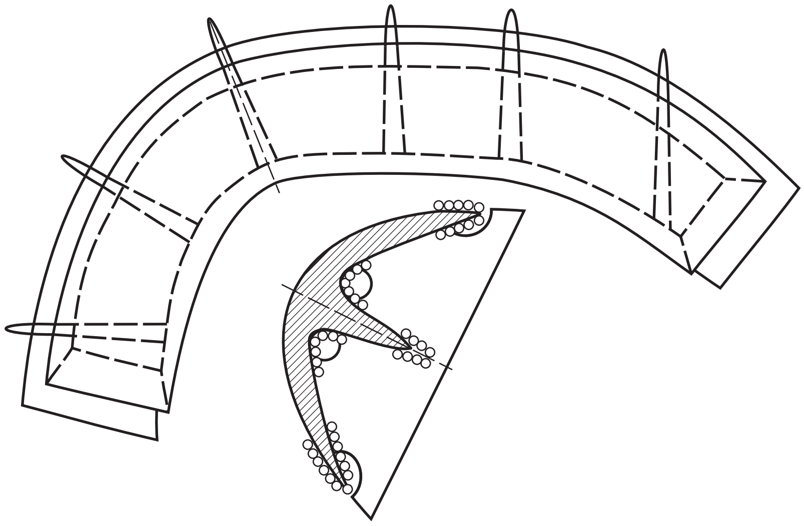
2.4.4 A set of three Charpy V-notch impact test specimens is to be provided with each casting in the Special grade. These may be taken from a small extension of the thickest part of the casting or from a block cast integrally with the casting and having dimensions representative of the largest section thickness of the casting. These are to be tested in accordance with Chapter 2 and are to have an average energy of not less than 27J at 0°C.

2.5 Non-destructive examination

2.5.1 Castings used in ship construction for the sternframe, rudder and propeller shaft supports are to be examined by ultrasonic and magnetic particle methods in accordance with 1.7. The type and extent of non-destructive examination of castings for other structural applications are to be specially agreed by the Surveyor.

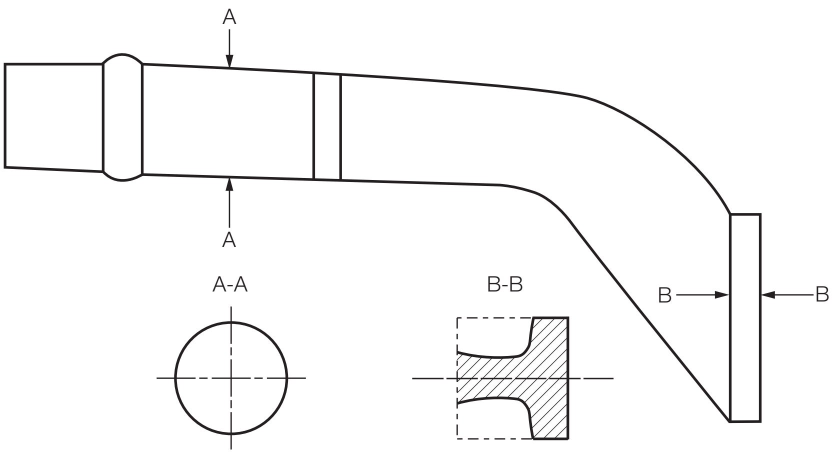
2.5.2 The extent and methods of non-destructive examination to be applied to typical hull steel castings are shown in Figs. 4.2.1 to 4.2.6 in addition to the areas specified in 1.7.9 and 1.7.10.

2.5.3 Acceptance levels for Visual Inspection are to be taken as follows:
(a) No cracks or hot tears are permitted.
(b) Castings are to be free of other injurious indications to the satisfaction of the Surveyor.
(c) Additional magnetic particle, dye penetrant or ultrasonic testing may be required for a more detailed evaluation of surface irregularities at the request of the Surveyor. These examinations are in addition to those required by 2.6.



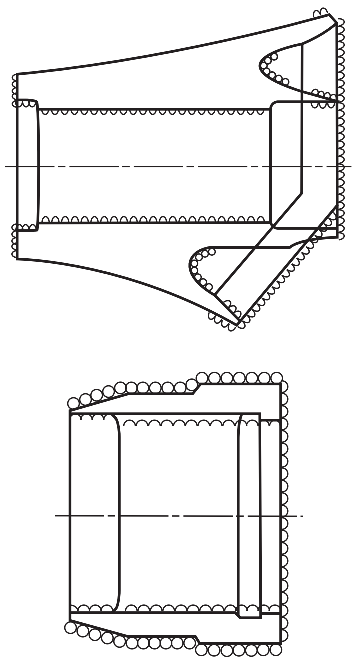
Location of non-destructive examination
1. All surfaces: Visual examination
2. Location indicated with (ooo): Magnetic particle and Ultrasonic testing

Fig. 4.2.1 Extent of non-destructive evaluation for stern frame castings



Location of non-destructive examination
All surfaces: Visual examination
Magnetic particle and ultrasonic testing

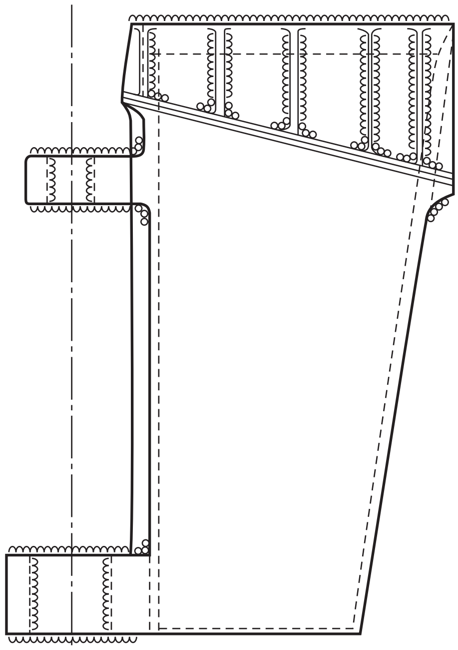
Fig. 4.2.2 Extent of non-destructive evaluation for rudder stock castings



Location of non-destructive examination

1. All surfaces: Visual examination
2. Location indicated with (ooo): Magnetic particle and ultrasonic testing
3. Location indicated with (⌒⌒⌒): Ultrasonic testing

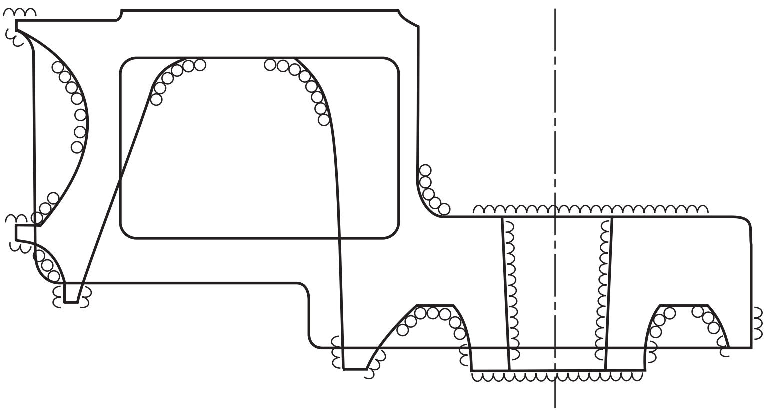
Fig. 4.2.3
Extent of non-destructive evaluation for stern boss castings



Location of non-destructive examination

1. All surfaces: Visual examination
2. Location indicated with (ooo): Magnetic particle and Ultrasonic testing
3. Location indicated with (⌒⌒⌒): Ultrasonic testing

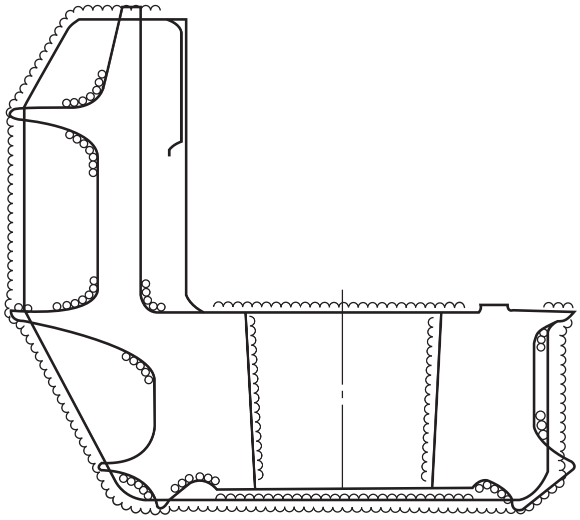
Fig. 4.2.4
Extent of non-destructive evaluation for rudder hanging castings



Location of non-destructive examination

1. All surfaces: Visual examination
2. Location indicated with (ooo): Magnetic particle and Ultrasonic testing
3. Location indicated with (⌒⌒⌒): Ultrasonic testing

Fig. 4.2.5 Extent of non-destructive evaluation for rudder (upper part) castings



Location of non-destructive examination
1. All surfaces: Visual examination
2. Location indicated with (ooo): Magnetic particle and Ultrasonic testing
3. Location indicated with (ᴗᴗᴗ): Ultrasonic testing

Fig. 4.2.6
Extent of non-destructive evaluation for rudder (lower part) castings

2.6 Acceptance levels for surface crack detection

2.6.1 The following definitions apply to indications associated with magnetic particle and dye penetrant inspection:

(a) **Linear indication**. An indication in which the length is at least three times the width.
(b) **Non-linear indication**. An indication of circular or elliptical shape with a length less than three times the width.
(c) **Aligned indication**. Three or more indications in a line, separated by 2 mm or less, edge-to-edge.
(d) **Open indication**. An indication visible after removal of the magnetic particles, or that can be detected by the use of contrast dye penetrant.
(e) **Non-open indication**. An indication that is not visually detectable after removal of the magnetic particles, or that cannot be detected by the use of contrast dye penetrant.
(f) **Relevant indication**. An indication that is caused by a condition or type of discontinuity that requires evaluation. Only indications which have any dimension greater than 1,5 mm are to be considered relevant.

2.6.2 For the purpose of evaluating indications, the surface is to be divided into reference band length of 150 mm for level MT1/PT1 and into reference areas of 225 cm^2 for level MT2/PT2. The band length and/or area is to be taken in the most unfavourable location, relative to the indications being evaluated.

2.6.3 The following quality levels recommended for magnetic particle testing (MT) and/or dye penetrant testing (PT) are;

(a) Level MT1/PT1 – fabrication weld preparation areas.
(b) Level MT2/PT2 – other locations indicated on Figs. 4.2.1 to 4.2.6.

The acceptance criteria are shown in Table 4.2.2. Cracks and hot tears are not acceptable.

2.6.4 Acceptance criteria for ultrasonic testing are shown in Table 4.2.3 as UT1 and UT2. Discontinuities within the examined zones interpreted to be cracks or hot tears, are not acceptable.

2.6.5 Level UT1 is applicable to the following:

(a) Fabrication weld preparations for a distance of 50 mm.
(b) 50 mm depth from the final machined surface including boltholes.
(c) Fillet radii to a depth of 50 mm and within a distance of 50 mm from the radius end.
(d) Castings subject to cyclic bending stresses, e.g., rudder horn, rudder castings and rudder stocks, the outer one third of thickness in the zones shown in Figs. 4.2.1 to 4.2.6.

2.6.6 Level UT2 is applicable to the following:

(a) For locations which are not specified in 2.6.5, nominated for ultrasonic testing in Figs. 4.2.1 to 4.2.6 or on the inspection plan.
(b) Positions outside locations nominated for level UT1 examination where feeders and gates have been removed.
(c) Castings subject to cyclic bending stresses, at the central one third of thickness in the zones shown in Figs. 4.2.1 to 4.2.6.

Table 4.2.2 Acceptance criteria for surface inspection evaluation

Quality level	Maximum number of indication	Type of indication	Maximum number each type	Maximum dimension of single indication, mm (*see* Note 2)
MT1/PT1	4 in 150 mm length	Non-linear Linear Aligned	4, *see* Note 1 4, *see* Note 1 4, *see* Note 1	5 3 3
MT2/PT2	20 in 22500 mm^2 area	Non-Linear Linear Aligned	10 6 6	7 5 5

NOTES
1. Minimum of 30 mm between relevant indications.
2. In weld repairs, the maximum dimension is 2 mm.

Table 4.2.3 Ultrasonic acceptance criteria for marine steel castings

Quality level	Allowable disc shape according to the Distance-Gain Size (DGS), mm	Maximum number of indications to be registered, *see* Note 1	Allowable length of linear indications, mm, *see* Note 2
UT1	>6	0	0
UT2	12–15 >15	5 0	50 0

NOTES
1. Grouped in an area measuring 300 x 300 mm.
2. Measured on the scanning surface.

2.6.7 Ultrasonic acceptance criteria for casting areas not nominated in Figs. 4.2.1 to 4.2.6 will be subject to special consideration, based on the anticipated stress levels and the type, size and position of the discontinuity.

2.6.8 Parts which are welded are to be examined by the same method as at the initial inspection as well as by additional methods as required by the Surveyor.

■ *Section 3* Castings for machinery construction

3.1 Scope

3.1.1 This Section gives the material requirements for carbon-manganese steel castings intended for use in machinery construction and which are not within the scope of Sections 4 to 7.

3.1.2 Where it is proposed to use steels of higher carbon content than is indicated in 3.2.1, or alloy steels, particulars of the chemical composition, mechanical properties and heat treatment are to be submitted for approval.

3.1.3 The manufacture or repair of cast steel connecting rods is not permitted, except where the manufacturing and quality control procedures have been approved by LR. For approval purposes, tests are to be carried out at the place of manufacture using the proposed process to demonstrate that the castings are sound. Tests are to be carried out to confirm that the appropriate mechanical properties are attained within the casting, including areas where weld repairs have been performed. Any changes to manufacturing, repair and quality control procedures are to be submitted to LR for approval, *see also* Ch 1,2.2.

3.2 Chemical composition

3.2.1 The chemical composition of ladle samples is to comply with the following limits, except as specified in 3.2.2:

Carbon	0,40% max.
Silicon	0,60% max.
Manganese	0,50–1,60%
Sulphur	0,040% max.
Phosphorus	0,040% max.
Residual elements:	
Copper	0,30% max.
Chromium	0,30% max.
Nickel	0,40% max.
Molybdenum	0,15% max.
	Total 0,80% max.

3.2.2 Castings which are intended for parts of a welded fabrication are to be of weldable quality with a carbon content generally not exceeding 0,23 per cent.

3.2.3 Proposals to use steels with higher carbon content, or alloy steels, for welded construction will be subject to special consideration.

3.3 Heat treatment

3.3.1 Castings are to be supplied:
(a) fully annealed; or
(b) normalised; or
(c) normalised and tempered at a temperature of not less than 550°C; or
(d) quenched and tempered at a temperature of not less than 550°C.

3.3.2 Engine bedplate castings, turbine castings and any other castings where dimensional stability and freedom from internal stresses are important, are to be given a stress relief heat treatment. This is to be at a temperature not lower than 550°C, followed by furnace cooling to 300°C or lower. Alternatively, full annealing may be used provided that the castings are furnace cooled to 300°C or lower.

3.4 Mechanical tests

3.4.1 At least one tensile test is to be made on material representing each casting or batch of castings.

3.4.2 Where the casting is of complex design, or where the finished mass exceeds 10 tonnes, two test samples are to be provided. Where large castings are made from two or more casts which are not mixed in a ladle prior to pouring, two or more test samples are required corresponding to the number of casts involved. The test samples are to be integrally cast at locations as widely separated as possible.

3.4.3 Table 4.3.1 gives the minimum requirements for yield stress, elongation and reduction of area corresponding to different strength levels, but it is not intended that these should necessarily be regarded as specific grades. Intermediate levels of minimum tensile strength may be specified, in which case minimum values for yield stress, elongation and reduction of area may be obtained by interpolation.

Table 4.3.1 Mechanical properties for acceptance purposes: carbon and carbon-manganese steel castings for machinery construction

Tensile strength N/mm^2	Yield stress N/mm^2 minimum	Elongation on $5,65\sqrt{S_o}$ % minimum	Reduction of area % minimum
400–550	200	25	40
440–590	220	22	30
480–630	240	20	27
520–670	260	18	25
560–710	300	15	20
600–750	320	13	20

3.4.4 Castings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Table 4.3.1.

3.4.5 The results of all tensile tests are to comply with the requirements of Table 4.3.1 appropriate to the specified minimum tensile strength.

3.4.6 For alloy steel castings and carbon-manganese steel castings containing more than 0,40 per cent carbon, the results of all mechanical tests are to comply with an approved specification.

3.4.7 When a casting, or a batch of castings, has failed to meet the mechanical test requirements, it may be re-heat treated and re-submitted for acceptance tests but this may not be carried out more than twice, *see* Ch 1,4.6.

3.5 Non-destructive examination

3.5.1 All piston crowns and cylinder covers are to be examined by ultrasonic testing. In addition, where these castings are intended for engines having a bore size larger than 400 mm, they are to be examined by magnetic particle or dye penetrant testing in accordance with 1.7.

3.5.2 Engine bedplate castings are to be examined by ultrasonic and magnetic particle or dye penetrant testing in accordance with 1.7.

3.5.3 Turbine castings are to be examined by magnetic particle or dye penetrant testing in accordance with 1.7. In addition, an ultrasonic or radiographic examination is to be made in way of fabrication weld preparations.

3.5.4 Other castings are to be examined by non-destructive methods where specified.

■ *Section 4* Castings for crankshafts

4.1 Scope

4.1.1 This Section gives the requirements for carbon and carbon-manganese steel castings for semi-built crankshafts.

4.1.2 Where it is proposed to use steels of higher carbon content than is indicated in 4.3.1, or alloy steels, particulars of the chemical composition, mechanical properties and heat treatment are to be submitted for approval. For alloy steels, the specified minimum tensile strength is not to exceed 700 N/mm^2.

4.2 Manufacture

4.2.1 The method of producing combined web and pin castings is to be approved. For this purpose, tests to demonstrate the soundness of the casting and the properties at important locations may be required.

4.3 Chemical composition

4.3.1 The chemical composition of ladle samples is to comply with the following limits:

Carbon	0,40% max. (*but see* 4.7.4(c))
Silicon	0,60% max.
Manganese	0,50–1,60%
Sulphur	0,040% max.
Phosphorus	0,040% max.
Residual elements:	
Copper	0,30% max.
Chromium	0,30% max.
Nickel	0,40% max.
Molybdenum	0,15% max.
	Total 0,80% max.

4.4 Heat treatment

4.4.1 Castings are to be supplied either:

(a) fully annealed and cooled in the furnace to a temperature of 300°C or lower; or
(b) normalised and tempered at a temperature of not less than 550°C, and cooled in the furnace to a temperature of 300°C or lower.

4.5 Mechanical tests

4.5.1 Proposals for the number of tests and the location of test material on the casting are to be submitted by the manufacturer.

4.5.2 Not less than one tensile test and three impact tests are to be made on material representing each casting. The impact tests are to be carried out at ambient temperature.

4.5.3 Table 4.4.1 gives the minimum requirements for yield stress and elongation corresponding to different strength levels, and it is not intended that these should necessarily be regarded as specific grades. The strength levels have been given in multiples of 40 N/mm^2 to facilitate interpolation for intermediate values of specified minimum tensile strength.

Table 4.4.1 Mechanical properties for acceptance purposes: carbon-manganese steel castings for crankshafts

Tensile strength N/mm^2	Yield stress N/mm^2 minimum	Elongation on $5,65\sqrt{S_o}$ % minimum	Reduction of area % minimum	Charpy V-notch impact tests average energy J minimum (*see* Note)
400–550	200	28	45	32
440–590	220	26	45	28
480–630	240	24	40	25
520–670	260	22	40	20
550–700	275	20	35	18

NOTE
Impact tests are to be made at ambient temperature.

4.5.4 Castings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Table 4.4.1.

4.5.5 The results of all tests are to comply with the requirements of Table 4.4.1 appropriate to the specified minimum tensile strength. For the impact tests, one individual value may be less than the required average value provided that it is not less than 70 per cent of this average value. *See* Ch 1,4.6 for re-test procedures.

4.6 Non-destructive examination

4.6.1 Magnetic particle examination is to be carried out over all surfaces in accordance with Fig. 4.4.1.

4.6.2 Each casting is to be examined by ultrasonic testing, and the extent of examination and defect acceptance criteria, using the DGS (Distance Gain Size) technique, are to be as shown in Fig. 4.4.2. Alternative ultrasonic procedures may be submitted for approval.

4.7 Rectification of defective castings

4.7.1 The requirements of 1.9 apply, except where amended by this Section.

4.7.2 Where castings have shallow surface defects, consideration is first to be given to removing such defects by grinding and blending or by machining the surface where there is excess metal on the Rule dimension.

4.7.3 Subject to prior agreement and submission of the detailed welding procedure for approval by LR, welding may be carried out prior to the final austenitising heat treatment.

4.7.4 Approval for welding will not be given in the following circumstances:

(a) For the rectification of repetitive defects caused by improper foundry technique or practice.
(b) For the building up by welding of surfaces or large shallow depressions.
(c) Where the carbon content of the steel exceeds 0,30 per cent.
(d) Where the carbon equivalent of the steel, given by $C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$ exceeds 0,65 per cent.

4.7.5 Provided that the Surveyors are satisfied that welding is justified, they may also authorise welding to the surfaces of crankwebs, following the final austenitising heat treatment, within the following limits:

(a) In general, the volume of the largest groove which is to be welded is not to exceed 3,2t cm^3, where t is the web axial thickness, in cm. The total volume of all grooves which are to be welded is not to exceed 9,6t cm^3 per crankweb.
(b) The welds do not extend within the cross-hatched zones marked on Fig. 4.4.3 for semi-built crank throws.
(c) Larger welds on balance weights may be permitted at the discretion of the Surveyor, provided that such repairs are wholly contained within the balance weight and do not affect the strength of the crankweb.

4.7.6 Subsequent to the final austenitising heat treatment, welding may be authorised in the surface of the bore for the journal (or pin) within the following limits:

(a) In general, the welds are to be not less than 125 mm apart.
(b) The welds are not to be located within circumferential bands of $\frac{t}{5}$ from the edges of the bores, nor at any position within the inner 120° arc of the bores, as cross-hatched on Fig. 4.4.3.
(c) The volume of the largest weld is to be not more than 1,1t cm^3, where t is the web axial thickness at the bore, in cm, and not more than three welds are to be made in any one bore surface.

4.7.7 After all defective material has been removed from a region, and this has been proven in the presence of the Surveyor by magnetic particle inspection or other suitable method, the excavation is to be suitably shaped to allow good access for welding.

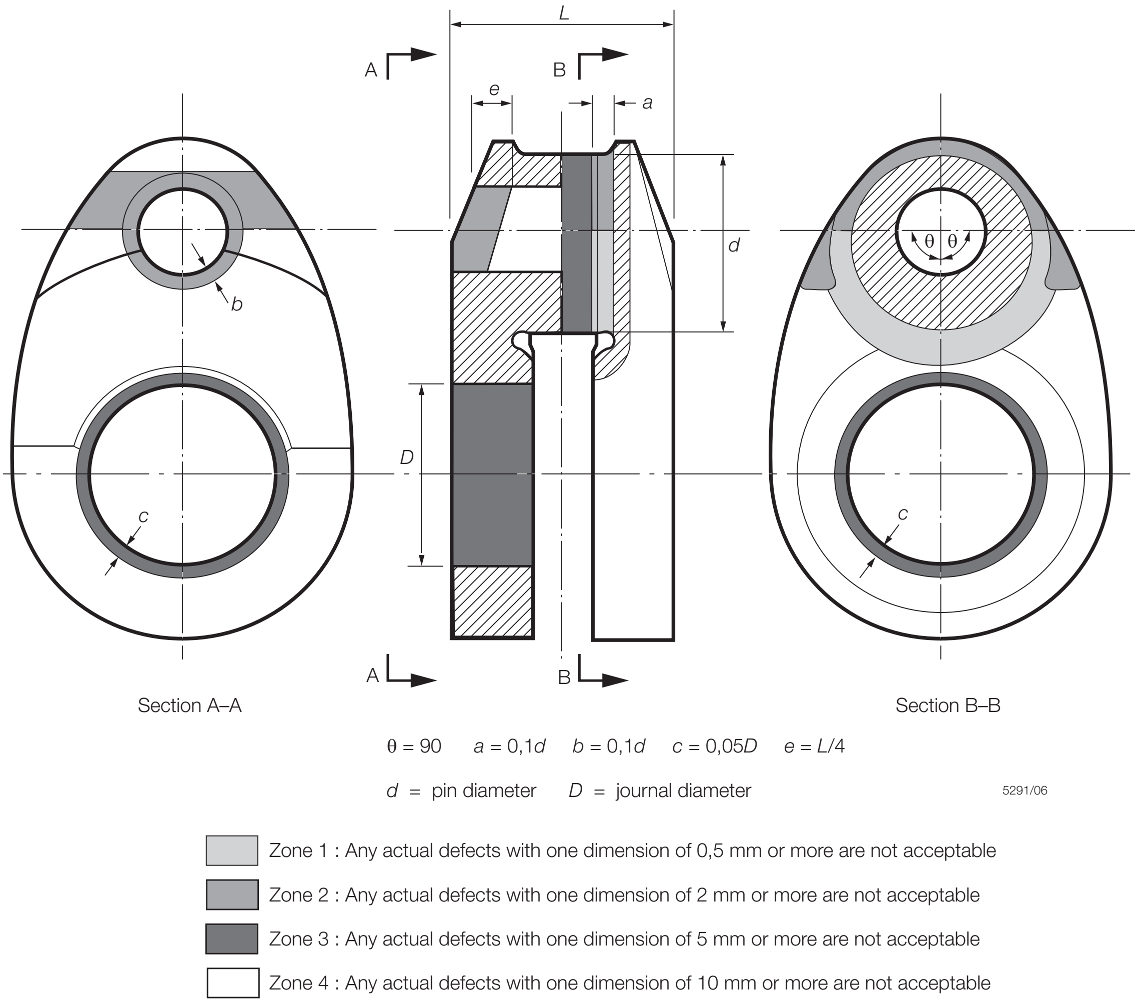


Fig. 4.4.1 Magnetic particle inspection acceptance levels

4.7.8 At the discretion of the Surveyor, the size of a groove may be increased beyond the limiting sizes given in 4.7.5 or 4.7.6, if the removal of further metal will facilitate welding.

4.7.9 Welding is to be carried out by approved welders using approved procedures. The welds are to be made by an electric arc process using low hydrogen type consumables which will produce a deposited metal that is not inferior in properties to the parent metal.

4.7.10 All castings are to be given a preliminary refining heat treatment prior to the commencement of welding. Before welding, the material is to be preheated in accordance with the qualified procedure. Where possible, preheating is to be carried out in a furnace. The preheat temperature is to be maintained until welding is completed, and preferably until the casting is placed in the furnace for post-weld heat treatment.

4.7.11 Where welding is carried out after the final austenitising heat treatments, a post-weld stress relieving heat treatment is to be applied at a temperature of not less than 600ºC, *see also* 1.5.2.

4.7.12 Welds are to be dressed smooth by grinding. The surfaces of the welds and adjacent parent steel are to be proven by magnetic particle and, where appropriate, ultrasonic inspection, *see* 1.9.15 and 1.9.14.

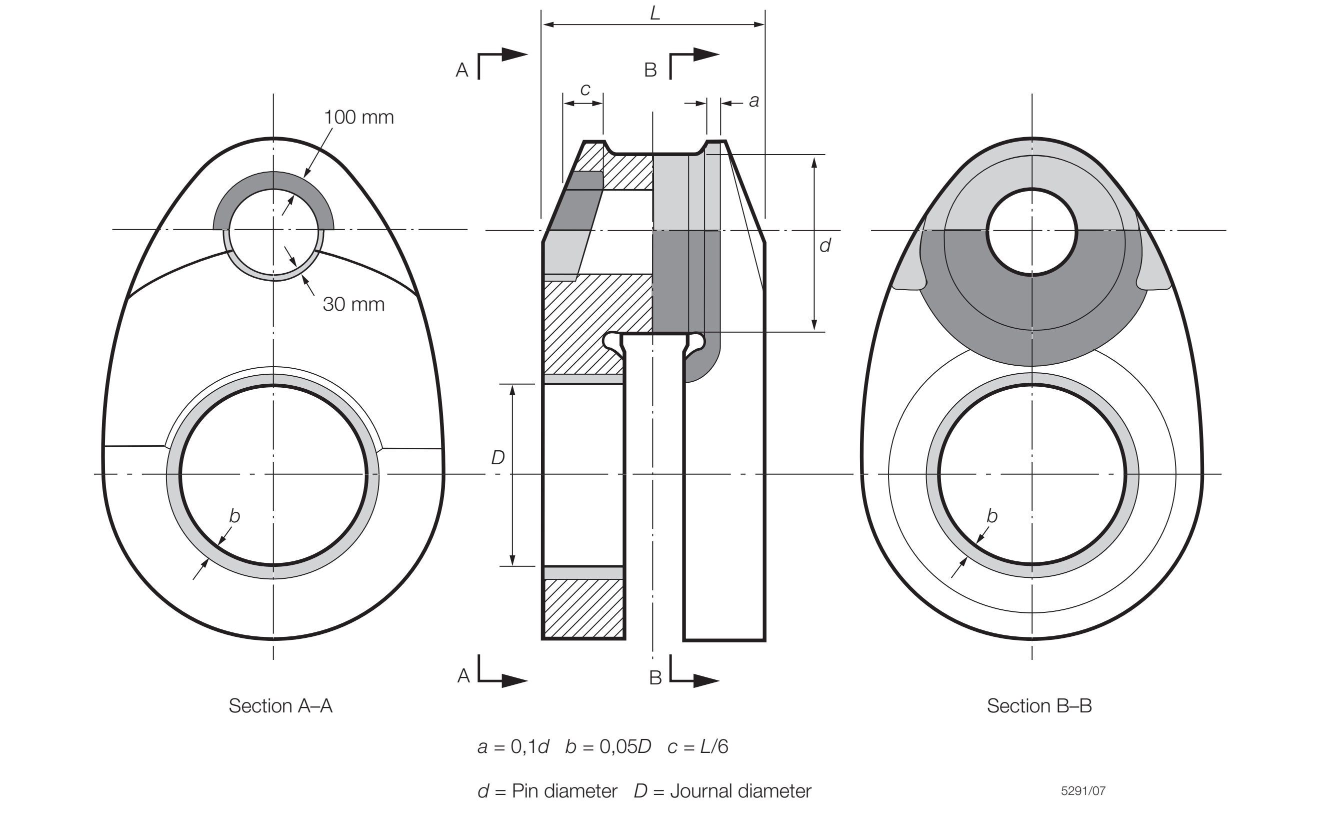


Fig. 4.4.2 Ultrasonic examination acceptance levels

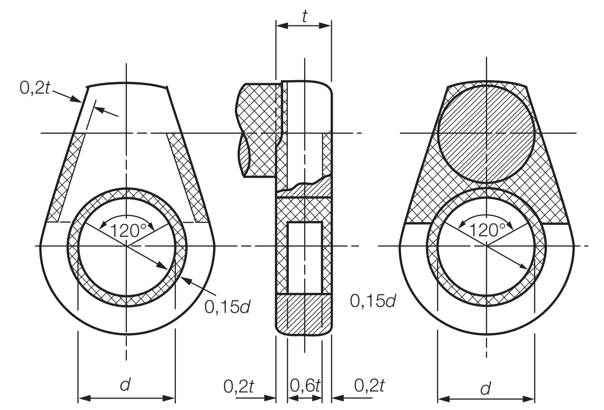


Fig. 4.4.3
Areas of semi-built crank throws to which weld repairs are not permitted

Section 5
Castings for propellers

5.1 Scope

5.1.1 This Section gives the requirements for steel castings for one-piece propellers and separately cast blades and hubs for fixed pitch and controllable pitch propellers (CPP). These include contra-rotating propellers, azipods and azimuth thrusters. The requirements for copper alloy propellers, blades and hubs are given in Ch 9,1.

5.1.2 These castings are to be manufactured and tested in accordance with the appropriate requirements of Chapters 1 and 2 and Ch 4,1 as well as the requirements of this Section.

5.1.3 Full details of the manufacturer's specification are to be submitted for approval. These should include the chemical composition, heat treatment, mechanical properties, micro-structure and repair procedures.

5.1.4 Special requirements are given for castings which are intended for ice service in Table 4.5.2.

5.2 Chemical composition

5.2.1 The chemical composition of ladle samples is to comply with the approved specification, *see* 5.1.3.

5.2.2 Typical cast steel propeller alloys are given in Table 4.5.1.

5.3 Heat treatment

5.3.1 Martensitic stainless steel castings are to be austenitised, quenched and tempered in accordance with the approved specification, *see* 5.1.3.

5.3.2 Austenitic stainless steel castings are to be solution treated in accordance with the approved specification, *see* 5.1.3.

5.4 Mechanical tests

5.4.1 The test material is to be cast integral with the boss of propeller castings, or with the flange of separately cast propeller blades. Alternatively, the test material may be attached on blades in an area between 0,5 and 0,6*R*, where *R* is the radius of the propeller.

5.4.2 The test material is not to be removed from the casting until final heat treatment has been carried out. Removal is to be by non-thermal procedures.

5.4.3 At least one tensile test and for the martensitic stainless steel grades one set of three Charpy V-notch impact tests are to be made on material representing each casting. The results are to comply with the requirements of Table 4.5.2 or the approved specification.

5.4.4 As an alternative to 5.4.3, where a number of small propeller castings of about the same size, and less than 1 m in diameter, are made from one cast and heat treated together in the same furnace, a batch testing procedure may be adopted using separately cast test samples of suitable dimensions. At least one set of mechanical tests is to be provided for each multiple of five castings in the batch.

5.4.5 Separately cast test bars may be used subject to prior approval of the Surveyor. Test bars must be cast from the same heat, or heats, and must also be heat treated with castings they represent.

5.5 Non-destructive examination

5.5.1 On completion of machining and grinding, the whole surface of each casting is to be examined in accordance with Ch 9,1.8.

5.5.2 When appropriate, magnetic particle inspection may be used in lieu of liquid penetrant testing.

5.5.3 Castings are to be free from cracks and hot tears.

Table 4.5.1 Typical chemical composition for steel propeller castings

Alloy type	C Max. (%)	Mn Max. (%)	Cr (%)	Mo Max. (%) (*see* Note)	Ni (%)
Martensitic (12Cr 1Ni)	0,15	2,0	11,5–17,0	0,5	Max. 2,0
Martensitic (13Cr 4Ni)	0,06	2,0	11,5–17,0	1,0	3,5–5,0
Martensitic (16Cr 5Ni)	0,06	2,0	15,0–17,5	1,5	3,5–6,0
Austenitic (19Cr 11Ni)	0,12	1,6	16,0–21,0	4,0	8,0–13,0

NOTE
Minimum values are to be in accordance with the agreed specification or recognised National or International Standards.

Table 4.5.2 Typical mechanical properties for steel propeller castings

Alloy type	Yield stress or, 0,2% proof stress minimum, N/mm^2	Tensile strength minimum N/mm^2	Elongation on 5,65 $\sqrt{S_o}$ % minimum	Reduction of area % minimum	Charpy V-notch impact tests J minimum (*see* Notes 1 and 2)
Martensitic (12Cr 1Ni)	440	590	15	30	20
Martensitic (13Cr 4Ni)	550	750	15	35	30
Martensitic (16Cr 5Ni)	540	760	15	35	30
Austenitic (19Cr 11Ni)	180 (*see* Note 3)	440	30	40	—

NOTES
1. When a general service notation **Ice Class 1AS, 1A, 1B or 1C** is required, the tests are to be made at –10°C.
2. For general service or where the notation **Ice Class 1D** is required, the tests are to be made at 0°C.
3. $R_{p1,0}$ value is 205 N/mm^2.

5.6 Rectification of defective castings

5.6.1 The rectification of defective castings is to be undertaken in accordance with 1.9 and the following paragraphs.

5.6.2 Removal of defective material is to be by mechanical means, e.g., by grinding, chipping or milling. The resultant grooves are to be blended into the surrounding surface so as to avoid any sharp contours.

5.6.3 Grinding in severity zone A may be carried out to an extent that maintains the blade thickness. Repair by welding is generally not permitted in zone A and will only be allowed after special consideration.

5.6.4 Defects in severity zone B that are not deeper than *t*/40 mm (*t* is the minimum local thickness according to the Rules) or 2 mm, whichever is the greater, are to be removed by grinding. Those defects that are deeper may be repaired by welding subject to prior approval of the Surveyor.

5.6.5 Repair welding is generally permitted in severity zone C.

5.6.6 Welds having an area of less than 5 cm^2 are to be avoided. The maximum surface area of repairs is to be in accordance with Table 9.1.4 in Chapter 9.

5.6.7 Welding is to be in accordance with the approved specification, *see* 5.1.3.

5.6.8 After weld repair, the propeller or blade is to be heat treated in such fashion as will minimise the residual stresses. For martensitic stainless steels, this will involve full heat treatment as specified in the approved specification.

5.6.9 LR reserves the right to restrict the amount of repair work accepted from a manufacturer when it appears that repetitive defects are the result of improper foundry techniques or practices.

5.6.10 All welds are to be inspected by the appropriate NDE method, *see* 1.7.

5.7 Identification

5.7.1 Castings are to be clearly marked by the manufacturer in accordance with the requirements of Chapter 1. The following details are to be shown on all castings which have been accepted:

(a) Identification mark which will enable the full history of the item to be traced.
(b) Type of steel, this should include or allow identification of the chromium and nickel contents.
(c) LR or Lloyd's Register and the abbreviated name of Lloyd's Register's local office.
(d) Personal stamp of Surveyor responsible for the final inspection.
(e) LR certificate number.
(f) Skew angle, if in excess of 25°.
(g) Ice class symbol, where applicable.
(h) Date of final inspection.

5.8 Certification of materials

5.8.1 In addition to the requirements in Ch 4,1.11, the manufacturer is to provide the Surveyor with a written statement giving the following particulars for each casting:

(a) Description of casting with drawing number.
(b) Diameter, number of blades, pitch, direction of turning.
(c) Skew angle, if in excess of 25°.
(d) Final mass.
(e) Vessel identification, where known.

■ *Section 6*
Castings for boilers, pressure vessels and piping systems

6.1 Scope

6.1.1 This Section gives the requirements for carbon-manganese and alloy steel castings for boilers, pressure vessels and piping systems for use at temperatures not lower than 0°C.

6.1.2 Where it is proposed to use alloy steels other than as given in this Section, details of the specification are to be submitted for approval. In such cases, the specified minimum tensile strength is not to exceed 600 N/mm^2.

6.1.3 Castings which comply with these requirements are acceptable for liquefied gas piping systems where the design temperature is not lower than 0°C. Where the design temperature is lower than 0°C, and for other applications where guaranteed impact properties at low temperatures are required, the castings are to comply with the requirements of Section 7 or 8.

6.2 Chemical composition

6.2.1 The chemical composition of ladle samples is to comply with the limits specified in Table 4.6.1.

6.3 Heat treatment

6.3.1 Castings are to be supplied:

(a) fully annealed; or
(b) normalised; or
(c) normalised and tempered; or
(d) quenched and tempered.

6.4 Mechanical tests

6.4.1 A tensile test is to be made on material representing each casting, unless a batch testing procedure has been agreed, *see* 1.6.

6.4.2 The tensile test is to be carried out at ambient temperature, and unless agreed otherwise with the Surveyor, the results are to comply with the requirements of Table 4.6.2.

Table 4.6.1 **Chemical composition of steel castings for boilers, pressure vessels and piping systems**

<table>
<tr><th rowspan="2">Type of steel</th><th colspan="11">Chemical composition %</th></tr>
<tr><th>C
max.</th><th>Si
max.</th><th>Mn</th><th>S
max.</th><th>P
max.</th><th colspan="6">Residual elements</th></tr>
<tr><td>Carbon-manganese</td><td>0,25</td><td>0,60</td><td>0,50-1,20</td><td>0,040</td><td>0,040</td><td colspan="6">Cr 0,30 max.
Mo 0,15 max.
Cu 0,30 max.
Ni 0,40 max.

Total 0,80 max.</td></tr>
<tr><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2">Cr</td><td rowspan="2">Mo</td><td rowspan="2">V</td><td colspan="3">Residual elements</td></tr>
<tr><td>Cr</td><td>Cu</td><td>Ni</td></tr>
<tr><td>1/2 Mo</td><td>0,20</td><td>0,60</td><td>0,50–1,00</td><td>0,040</td><td>0,040</td><td>—</td><td>0,45-0,65</td><td>—</td><td>0,30 max.</td><td>0,30 max.</td><td>0,40 max.</td></tr>
<tr><td>1 Cr 1/2 Mo</td><td>0,20</td><td>0,60</td><td>0,50-0,80</td><td>0,040</td><td>0,040</td><td>1,00-1,50</td><td>0,45-0,65</td><td>—</td><td>—</td><td>0,30 max.</td><td>0,40 max.</td></tr>
<tr><td>2 1/4 Cr1 Mo</td><td>0,18</td><td>0,60</td><td>0,40-0,70</td><td>0,040</td><td>0,040</td><td>2,00-2,75</td><td>0,90-1,20</td><td>—</td><td>—</td><td>0,30 max.</td><td>0,40 max.</td></tr>
<tr><td>1/2 Cr 1/2 Mo 1/4 V</td><td>0,10–0,15</td><td>0,45</td><td>0,40-0,70</td><td>0,030</td><td>0,030</td><td>0,30-0,50</td><td>0,40-0,60</td><td>0,22-0,30</td><td>—</td><td>0,30 max.</td><td>0,30 max.</td></tr>
</table>

Table 4.6.2 **Mechanical properties for acceptance purposes: steel castings for boilers, pressure vessels and piping systems**

Type of steel	Yield stress minimum N/mm^2	Tensile strength N/mm^2	Elongation on $5,65\sqrt{S_o}$ % minimum	Reduction of area % minimum
Carbon-manganese	275	485-655	22	25
1/2Mo	260	460-590	18	30
1Cr1/2Mo	280	480-630	17	20
21/4 Cr1 Mo	325	540-630	17	20
1/2Cr1/2Mo1/4V	295	510-660	17	20

6.4.3 Where it is proposed to use a carbon-manganese steel with a specified minimum tensile strength intermediate to those given in this Section, corresponding minimum values for the yield stress, elongation and reduction of area may be obtained by interpolation.

6.4.4 Carbon-manganese steels with a specified minimum tensile strength of greater than 490 N/mm^2, but not exceeding 520 N/mm^2, may be accepted provided that details of the proposed specification are submitted for approval.

6.5 Non-destructive examination

6.5.1 The non-destructive examination of castings is to be carried out in accordance with the appropriate requirements of 1.7.7 to 1.7.11 and additionally as agreed between the manufacturer, purchaser and Surveyor.

6.6 Mechanical properties for design purposes

6.6.1 Nominal values for the minimum lower yield or 0,2 per cent proof stress at temperatures of 100°C and higher are given in Table 4.6.3. These values are intended for design purposes only, and verification is not required except for materials complying with National or proprietary specifications where the elevated temperature properties used for design purposes are higher than those given in Table 4.6.3.

6.6.2 In such cases, at least one tensile test at the proposed design or other agreed temperature is to be made on each casting or each batch of castings. The test specimen is to be taken from material adjacent to that used for tests at ambient temperature, and the test procedure is to be in accordance with the requirements of Chapter 2. The results of all tests are to comply with the requirements of the National or proprietary specification.

6.6.3 Values for the estimated average stress to rupture in 100 000 hours are given in Table 4.6.4 and may be used for design purposes.

Table 4.6.3 **Mechanical properties for design purposes** (*see* 6.6.1)

Type of steel	Nominal minimum lower yield or 0,2% proof stress N/mm^2										
	Temperature °C										
	100	150	200	250	300	350	400	450	500	550	600
Carbon-manganese	225	214	201	186	163	156	152	—	—	—	—
$^1/_2$Mo	242	236	226	207	186	175	169	158	145	136	126
1Cr$^1/_2$Mo	240	—	212	—	196	—	184	—	160	—	117
2$^1/_4$Cr1 Mo	323	312	305	296	290	280	273	258	240	211	180
$^1/_2$Cr$^1/_2$Mo$^1/_4$V	264	—	244	—	230	—	214	—	194	—	144

Table 4.6.4 **Mechanical properties for design purposes** (*see* 6.6.3)**: estimated average stresses to rupture in 100,000 hours (N/mm^2)**

Temperature °C	Type of steel			
	$^1/_2$Mo	1Cr$^1/_2$Mo	2$^1/_4$Cr1Mo	$^1/_2$Cr$^1/_2$Mo$^1/_4$V
430	308	—	—	—
440	276	—	—	—
450	245	—	222	277
460	212	—	199	237
470	174	236	177	206
480	133	186	156	181
490	103	148	139	159
500	84	120	124	140
510	71	100	111	124
520	60	84	99	109
530	—	70	—	96
540	—	58	—	85
550	—	—	—	75
560	—	—	—	66

■ Section 7
Ferritic steel castings for low temperature service

7.1 Scope

7.1.1 This Section gives the requirements for castings in carbon-manganese and nickel alloy steels, intended for use in liquefied gas piping systems where the design temperature is lower than 0°C, and for other applications where guaranteed impact properties at low temperatures are required.

7.1.2 Where it is proposed to use alternative steels, particulars of the specified chemical composition, mechanical properties and heat treatment are to be submitted for approval.

7.2 Chemical composition

7.2.1 The chemical composition of ladle samples is to comply with the limits specified in Table 4.7.1. Carbon-manganese steels are to be made by fine grain practice.

7.3 Heat treatment

7.3.1 Castings are to be supplied:
(a) normalised; or
(b) normalised and tempered; or
(c) quenched and tempered.

7.4 Mechanical tests

7.4.1 One tensile test and one set of three Charpy V-notch impact test specimens are to be prepared from material representing each casting or batch of castings.

7.4.2 The tensile test is to be carried out at ambient temperature, and the results are to comply with the appropriate requirements given in Table 4.7.2.

7.4.3 The average value for impact test specimens is to comply with the appropriate requirements given in Table 4.7.2. One individual value may be less than the required average value provided that it is not less than 70 per cent of this average value. *See* Ch 2,1.4 for re-test procedure.

7.5 Non-destructive examination

7.5.1 The non-destructive examination of castings is to be carried out in accordance with the appropriate requirements of 1.7.7 to 1.7.11 and additionally agreed between the manufacturer, purchaser and Surveyor.

Table 4.7.1 Chemical composition of ferritic steel castings for low temperature service

Type of steel	Chemical composition %						
	C max.	Si max.	Mn	S max.	P max.	Ni	Residual elements max.
Carbon-manganese	0,25	0,60	0,70-1,60	0,030	0,030	0,80 max.	Cr 0,25 Cu 0,30 Mo 0,15 V 0,03 Total 0,60
$2^1/_4$Ni	0,25	0,60	0,50-0,80	0,025	0,030	2,00-3,00	
$3^1/_2$Ni	0,15	0,60	0,50-0,80	0,020	0,025	3,00-4,00	

Table 4.7.2 Mechanical properties for acceptance purposes: ferritic steel castings for low temperature service

Type of steel	Grade	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on 5,65 $\sqrt{S_o}$ % minimum	Reduction or area % minimum	Charpy V-notch impact test	
						Test temperature °C	Average energy J minimum
Carbon-manganese	400 430 460	200 215 230	400-550 430-580 460-610	25 23 22	40 35 30	–60 (*see* Note)	27
$2^1/_4$Ni	490	275	490-640	20	35	–70	34
$3^1/_2$Ni	490	275	490-640	20	35	–95	34

NOTE
The test temperature for carbon-manganese steels may be 5°C below the design temperature if the latter is above –55°C, with a maximum test temperature of –20°C.

■ *Section 8*
Stainless steel castings

8.1 Scope

8.1.1 This Section gives the requirements for castings in austenitic and duplex stainless steels for machinery, marine structures, piping systems in ships for liquefied gases, and in bulk chemical tankers.

8.1.2 Austenitic stainless steels castings are suitable for applications where the lowest design temperature is not lower than –165°C.

8.1.3 Duplex stainless steels castings are suitable for applications where the lowest design temperature is above 0°C. Any requirement to use duplex stainless steels castings below 0°C will be subject to special consideration.

8.1.4 Where it is proposed to use alternative steels, particulars of the specified chemical composition, mechanical properties and heat treatment are to be submitted for approval.

8.2 Chemical composition

8.2.1 The chemical composition of ladle samples is to comply with the requirements given in Table 4.8.1.

8.3 Heat treatment

8.3.1 Austenitic stainless steel castings are to be solution treated, at a temperature of not less than 1000°C and cooled rapidly in water.

8.3.2 Duplex stainless steels castings are to be solution treated at a temperature of not less that 1100°C and cooled rapidly in water.

8.4 Mechanical tests

8.4.1 One tensile test specimen is to be prepared from material representing each casting or batch of castings. In addition, where the castings are intended for liquefied gas applications, where the design temperature is lower than –55°C, one set of three Charpy V-notch impact test specimens is to be prepared.

8.4.2 The tensile test is to be carried out at ambient temperature, and the results are to comply with the requirements given in Table 4.8.2.

Table 4.8.1 Chemical composition of stainless steel castings

Type of steel	Chemical composition %								
	C	Si	Mn	S	P	Cr	Mo	Ni	Others
Austenitic									
304L	0,03	0,20-1,5	0,50-2,0	0,040		17,0-21,0	—	8,0–12,0	—
304	0,08						—	8,0–12,0	—
316L	0,03						2,0–3,0	9,0–13,0	—
316	0,08						2,0–3,0	9,0–13,0	—
317	0,08						3,0–4,0	9,0–12,0	—
347 (*see* Note 1)	0,06						—	9,0–12,0	Nb ≥ 8 x C ≤ 0,90
Duplex									
UNS S 31803	0,03	1,00	2,00	0,025	0,035	21,0–23,0	2,5–3,5	4,5–6,5	N 0,08–0,20

NOTES
1. When guaranteed impact values at low temperature are not required, the maximum carbon content may be 0,08% and the maximum niobium may be 1,00%.
2. Where a single value is shown (and not a range of values), the value is to be taken as maximum.

Table 4.8.2 Mechanical properties for acceptance purposes: stainless steel castings

Type of steel	Tensile strength N/mm^2 minimum	1,0% proof stress N/mm^2 minimum	Elongation on $5,65 \sqrt{S_o}$ % minimum	Reduction of area % minimum	Charpy V-notch impact tests	
					Test temperature °C	Average energy J minimum
Austenitic						
304L	430	215	26	40	–196	41
304	480	220				
316L	430	215	26	40	–196	41
316	480	220				
317	480	240				
347	480	215	22	35	–196	41
Duplex						
UNS S 31803	600	420	20	35	0	41

8.4.3 The average value for impact test specimens is to comply with the appropriate requirements given in Table 4.8.2. One individual value may be less than the required average value, provided that it is not less than 70 per cent of this average value. *See* Ch 2,1.4 for re-test procedures.

8.5 Intergranular corrosion tests

8.5.1 Where corrosive conditions are anticipated in service, intergranular corrosion tests are required on castings in grades 304, 316, 317 and all duplex stainless steels. Such tests may not be required for grades 304L, 316L and 347.

8.5.2 Where an intergranular corrosion test is specified, it is to be carried out in accordance with the procedure given in Ch 2,9.1.

8.6 Non-destructive examination

8.6.1 The non-destructive examination of castings is to be carried out in accordance with the appropriate requirements of 1.7.7 to 1.7.11 and additionally agreed between the manufacturer, purchaser and Surveyor.

■ *Section 9*
Steel castings for container corner fittings

9.1 General

9.1.1 This Section gives the requirements for cast steel corner fittings used in the fabrication of freight and tank containers. The fittings are also to comply with the requirements of the latest edition of International Standard ISO 1161.

9.1.2 The castings are to be made in foundries approved by LR. These foundries are also to be specially approved for the manufacture of container corner castings. In order to comply with these requirements, the manufacturer is required to verify that the casting soundness, mechanical properties, weldability and dimensional tolerances required by this Section and the manufacturing specification are met.

9.1.3 Castings may be released on the basis of an LR survey or, alternatively, the manufacturer may be approved by means of a Quality Assurance Scheme as detailed in Ch 1,2.

9.2 Chemical composition

9.2.1 Chemical analysis is to be carried out on each cast.

9.2.2 The chemical composition of the ladle samples is to comply with the limits given in Table 4.9.1.

9.2.3 The carbon equivalent:

$$C_{eq} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15} \ (\%)$$

must not exceed 0,45 per cent.

9.3 Heat treatment

9.3.1 Castings are to be supplied either:
(a) normalised; or
(b) water or oil quenched and tempered at a temperature of not less than 550°C.

9.4 Mechanical tests

9.4.1 At least one tensile test is to be made on each batch of castings, using separately cast test bars which are to be from the same cast and heat treatment lot as the castings they represent.

9.4.2 The results of the tensile tests are to comply with the following:

Yield stress	220 N/mm^2 min.
Tensile strength	430–600 N/mm^2
Elongation on $\sqrt{S_o}$	25% min.
Reduction of area	40% min.

9.4.3 Impact tests are not required on all casts, but may be required on a random basis at the discretion of the Surveyor.

9.4.4 When required, the impact test specimens are to be tested in accordance with Ch 1,4.5 and Ch 2,3.2. In general, tests are to be made at a temperature of –20°C and the minimum average energy obtained is to be 27J.

9.5 Non-destructive examination

9.5.1 Ultrasonic or radiographic testing is to be carried out, in accordance with 1.7.10 or 1.7.11 respectively, on at least one casting from each cast or from every 400 castings, whichever is the lesser.

9.6 Repair of defects

9.6.1 Minor defects may be removed by grinding provided that the allowable minus tolerance is not exceeded.

Table 4.9.1 Chemical composition of steel castings for container corner fittings

Chemical composition %										
C max.	Mn	Si max.	P max.	S max.	Cr max.	Ni max.	Cu max.	Mo max.	Al acid soluble min. (*See* Notes)	Cr + Ni + Cu + Mo max.
0,20	0,90 to 1,50	0,50	0,035	0,035	0,25	0,30	0,20	0,08	0,015	0,70

NOTES
1. The total aluminium content may be determined instead of the acid soluble content. In such cases, the total aluminium content is to be not less than 0,02%.
2. Aluminium may be replaced partly or totally by other grain refining elements as stated in the approved specification.

9.6.2 Defects which exceed the allowable minus tolerance may be removed by grinding or chipping followed by welding, provided the weld depth does not exceed 40 per cent of the wall thickness and that the following requirements are met:

(a) welding is not to be carried out in the as-cast condition; the grain structure has to be refined by heat treatment,
(b) the casting is to be preheated to 80–100°C,
(c) welding is to be performed only by qualified welders in accordance with a qualified welding procedure,
(d) all welded castings are to be post-weld heat treated at a temperature not less than 550°C,
(e) the welded areas are to be ground or machined flush with the adjacent surface and inspected by magnetic particle or dye penetrant examination as appropriate.

9.7 Identification

9.7.1 Each casting is to be clearly marked by the manufacturer with at least the following:

(a) manufacturer's name or trade mark,
(b) cast number or identification number which will enable the full history of the casting to be traced.

9.7.2 Where the casting has been inspected and found acceptable it is to be marked with the Surveyor's personal stamp.

9.7.3 The markings may be stamped or cast on the inner surface of the casting.

9.8 Certification of materials

9.8.1 For each consignment a manufacturer's certificate is to be issued (*see* Ch 1,3.1), containing at least the following:

(a) Purchaser's name and order number.
(b) Grade of steel.
(c) Drawing and/or specification number.
(d) Cast number and chemical composition.
(e) Details of the heat treatment.
(f) Number and weight of the castings.
(g) Results of inspections and mechanical tests.

Section

■ *Section 1* General requirements

1.1 Scope

1.1.1 This Section gives the general requirements for steel forgings intended for use in the construction of ships, other marine structures, machinery, boilers, pressure vessels and piping systems. These requirements are also applicable to rolled slabs and billets used as a substitute for forgings and to rolled bars used for the manufacture (by machining operations only) of shafts, bolts, studs and other components of similar shape.

1.1.2 When required by the relevant Rules dealing with design and construction, forgings are to be manufactured and tested in accordance with Chapters 1 and 2, together with the general requirements given in this Section and the appropriate specific requirements given in Sections 2 to 9.

1.1.3 As an alternative to 1.1.2, steel forgings which comply with National or proprietary specifications, may be accepted provided that these specifications give reasonable equivalence to the requirements of this Chapter, or alternatively are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

1.1.4 Normalised forgings with mass up to 1000 kg each may be batch tested. A batch is to consist of forgings of similar shape and dimensions, made from the same steel-making heat, heat treated together and with a total mass not exceeding 6 tonnes.

1.1.5 Quenched and tempered forgings with mass up to 500 kg each may be batch tested. A batch is to consist of forgings of similar shape and dimensions, made from the same steel-making heat, heat treated together in the same furnace and with a total mass not exceeding 3 tonnes.

1.1.6 A batch testing procedure may also be used for hot rolled bars, *see* 3.4.3.

1.1.7 Where small forgings are produced in large quantities, or where forgings of the same type are produced in regular quantities, alternative survey procedures in accordance with Ch 1,2.4 may be adopted.

1.2 Manufacture

1.2.1 Forgings are to be made at works which have been approved by Lloyd's Register (hereinafter referred to as LR). The steel used, is to be manufactured in accordance with the requirements of Ch 3,1.4.

1.2.2 When forgings are made directly from ingots, or from blooms or billets forged from ingots, the ingots are to be cast in chill moulds with the larger cross-section uppermost and with efficient feeder heads.

1.2.3 Adequate top and bottom discards are to be made to ensure freedom from piping and harmful segregations in the finished forgings.

1.2.4 The forgings are to be gradually and uniformly hot worked and are to be formed as closely as possible to the finished shape and size. The plastic deformation is to be such as to ensure soundness, uniformity of structure and satisfactory mechanical properties after heat treatment.

1.2.5 For certain components, such as crankshafts, where grain flow is required in the most favourable direction, having regard to the mode of stressing in service, the proposed method of manufacture may require special approval by LR. In such cases, tests may be required to demonstrate that a satisfactory structure and grain flow are obtained.

1.2.6 The reduction ratio (reduction of area expressed as a ratio) is to be calculated with reference to the average cross-sectional area of the ingot or continuously cast material, where appropriate. Where an ingot is initially upset, this reference area may be taken as the average cross-sectional area after this operation.

1.2.7 For components forged directly from ingots or from forged blooms or billets, and in which the fibre deformation is mainly longitudinal, the reduction ratio is not to be less than 3:1.

1.2.8 For forgings made from rolled billets, or where fibre deformation has taken place in more than one direction, the reduction ratio is not to be less than 4:1.

1.2.9 Where rolled bars are used as a substitute for forgings and the requirements of 1.2.2 are not complied with, the reduction ratio is to be not less than 6:1.

1.2.10 Where the length of any section of a shaft forging is less than its diameter (e.g., a collar), the reduction ratio is to be not less than half that given in 1.2.7, 1.2.8 or 1.2.9 respectively.

1.2.11 Disc type forgings, such as gear wheels, are to be made by upsetting, and the thickness of any part of the disc is to be not more than one-half of the length of the billet from which it was formed, provided that this billet has received an initial forging reduction of not less than 1,5:1. Where the piece used has been cut directly from an ingot, or where the billet has received an initial reduction of less than 1,5:1, the thickness of any part of the disc is to be not more than one-third of the length of the original piece.

1.2.12 Rings and other types of hollow forgings are to be made from pieces cut from ingots or billets and which have been suitably punched, bored or trepanned prior to expanding or hollow forging. Alternatively, pieces from hollow cast ingots may be used. The wall thickness of the forging is to be not more than one-half of the thickness of the prepared hollow piece from which it was formed. Where this is not practicable, the forging procedure is to be such as to ensure that adequate work is given to the piece prior to punching, etc. This may be either longitudinal or upset working of not less than 2:1.

1.2.13 The shaping of forgings or rolled slabs and billets by flame cutting, scarfing or arc-air gouging is to be undertaken in accordance with recognised good practice and, unless otherwise approved, is to be carried out before the final heat treatment. Preheating is to be employed where necessitated by the composition and/or thickness of the steel. For certain components, subsequent machining of all flame cut surfaces may be required, *see* 4.2.4.

1.2.14 Where two or more forgings are joined by welding to form a composite component, details of the proposed welding procedure are to be submitted for approval. Welding approval procedure tests may be required.

1.3 Quality

1.3.1 All forgings are to be free from surface or internal defects which would be prejudicial to their proper application in service.

1.4 Chemical composition

1.4.1 All forgings are to be made from killed steels, and the chemical composition of ladle samples is to comply with the requirements detailed in subsequent Sections in this Chapter. Where general overall limits are specified, the chemical composition selected is to be appropriate for the type of steel, dimensions and required mechanical properties of the forgings being manufactured.

1.4.2 Except where otherwise specified, suitable grain refining elements such as aluminium, niobium or vanadium may be used at the discretion of the manufacturer. The content of such elements is to be reported in the ladle analysis.

1.4.3 For alloy steel forgings, the chemical composition of ladle samples is to generally comply with the following overall limits and the requirements of the approved specifications:

Carbon	0,45% max.
Silicon	0,45% max.
Manganese	0,30% min.
Sulphur	0,035% max.
Phosphorus	0,035% max.
Copper	0,30% max.

And at least one of the following elements is to comply with the minimum content:

Chromium	0,40% min.
Molybdenum	0,15% min.
Nickel	0,40% min.

The contents of all alloying elements and significant impurities detailed in the specification are to be reported.

1.5 Heat treatment

1.5.1 At an appropriate stage of manufacture, after completion of all hot working operations, forgings are to be suitably heat treated to refine the grain structure and to obtain the required mechanical properties. Acceptable heat treatment procedures are to be such as to avoid the formation of hair-line cracks and are detailed in Sections 2 to 9.

1.5.2 Heat treatment is to be carried out in a properly constructed furnace which is efficiently maintained and has adequate means of temperature control. The furnace dimensions are to be such as to allow all the steel forgings to be uniformly heated to the necessary temperature. In the case of very large forgings, alternative methods of heat treatment will be specially considered. Sufficient thermocouples are to be connected to the steel forging(s) in the furnace to show that the temperature is adequately uniform and the temperatures are to be recorded throughout the heat treatment. Copies of these records are to be presented to the Surveyor together with a sketch showing the positions at which the temperature measurements were carried out. The records are to identify the furnace that was used and give details of the steel-making heat, the heat treatment temperature, time at temperature and the date. The Surveyor is to examine the charts and confirm the details on the certificate. Alternative procedures are to be approved by LR's Materials and NDE Department.

1.5.3 Where forgings are to be quenched and tempered and cannot be hot worked close to size and shape, they are to be suitably rough machined or flame cut prior to being subjected to this treatment.

1.5.4 If for any reason a forging is subsequently heated for further hot working, the forging is to be reheat treated.

1.5.5 If any straightening operation is performed after the final heat treatment, consideration should be given to a subsequent stress relieving heat treatment in order to avoid the possibility of harmful residual stresses.

1.5.6 Where it is intended to surface harden forgings, full details of the proposed procedure and specification are to be submitted for approval. For the purposes of this approval, the manufacturer will be required to demonstrate by tests that the proposed procedure gives a uniform surface layer of the required hardness and depth and that it does not impair the soundness and properties of the steel.

1.5.7 Where induction hardening or nitriding is to be carried out after machining, forgings are to be heat treated at an appropriate stage to a condition suitable for this subsequent surface hardening.

1.5.8 Where carburising is to be carried out after machining, forgings are to be heat treated at an appropriate stage (generally either by full annealing or by normalising and tempering) to a condition suitable for subsequent machining and carburising.

1.5.9 The forge is to maintain records of heat treatment identifying the furnace used, furnace charge, thermocouple location, date, temperature and time at temperature. The records are to be presented to the Surveyor on request.

1.6 Test material

1.6.1 Test material, sufficient for the required tests and for possible re-test purposes, is to be provided with a cross-sectional area of not less than that part of the forging which it represents. This test material is to be integral with each forging, except in the case of small forgings which are batch tested, *see* 1.6.4.

1.6.2 Where a forging is subsequently divided into a number of components, all of which are heat treated together in the same furnace, for test purposes this may be regarded as one forging and the number of tests required is to be related to the total length and mass of the original multiple forging, *see* 2.4.2.

1.6.3 Except for components which are to be carburised, test material is not to be cut from a forging until the heat treatment detailed in Sections 2 to 9 has been completed. The testing procedure for components which are to be carburised is to be in accordance with the details given in Section 5.

1.6.4 Where a number of small forgings of about the same size are made from one cast and heat treated together in the same furnace, batch testing procedures (*see* 1.1.4) may be adopted using one of the forgings for test purposes, or alternatively using separately forged test samples. These test samples are to have a forging reduction similar to that used for the forgings which they represent. They are to be properly identified and heat treated together with the forgings.

1.7 Mechanical tests

1.7.1 Specimens for mechanical tests are to be prepared as required by Sections 2 to 9.

1.7.2 Test specimens are normally to be cut with their axes mainly parallel (longitudinal test) or mainly tangential (tangential test) to the principal axial direction of each product.

1.7.3 Unless otherwise agreed, the longitudinal axis of the test specimens is to be positioned as follows:

(a) for thickness or diameter ≤ 50 mm, the axis is to be at the mid-thickness or the centre of the cross-section;
(b) for thickness or diameter > 50 mm, the axis is to be at one quarter thickness (mid-radius) or 80 mm, whichever is less, below any heat treated surface;

Test pieces shall be taken in such a way that no part of the gauge length is machined from material closer than 12,5 mm to any heat treated surface. For impact testing, this requirement is to apply to the complete test piece.

1.7.4 Tensile test specimens are to be machined to the dimensions detailed in Chapter 2. Where this is precluded by the dimensions of the forging, the test specimen is to be of the largest practicable cross-sectional area.

1.7.5 Impact test specimens are to be prepared in accordance with the requirements of Chapter 2.

1.7.6 The procedures used for the tensile and impact tests are to be in accordance with the requirements of Chapter 2.

1.7.7 Hardness tests, preferably of the Brinell type, are to be carried out when specified in subsequent Sections in this Chapter.

1.8 Visual and non-destructive examination

1.8.1 Before acceptance, all forgings are to be presented to the Surveyor for visual examination. Where applicable, this is to include the examination of internal surfaces and bores.

1.8.2 Forgings are to be examined in the condition for final delivery. Surfaces are to be clean and free from dirt, grease, paint, etc. Black forgings are to be suitably descaled by either shotblasting or flame descaling methods.

1.8.3 All forgings are to be free of cracks, crack-like indications, laps, seams, folds, or other injurious indications. At the request of the Surveyor, additional magnetic particle, dye penetrant and ultrasonic testing may be required for a more detailed evaluation of surface irregularities.

1.8.4 When specified in subsequent Sections in this Chapter, or by an approved procedure for welding composite components, *see* 1.2.14, appropriate non-destructive examination is also to be carried out before acceptance. All tests are to be carried out in accordance with the requirements of Ch 1,5.

1.8.5 Magnetic particle and dye penetrant testing is to be carried out when the forgings are in the finished machined condition, *see also* Ch 1,2.3.5. For magnetic particle testing, attention is to be paid to the contact between the forging and the clamping devices of stationary magnetisation benches in order to avoid local overheating or burning damage on its surface. Prods are not permitted on finished machined items. Unless otherwise agreed, these tests are to be carried out in the presence of the Surveyor.

1.8.6 The following definitions apply to indications associated with magnetic particle and dye penetrant inspection:

(a) **Linear indication**. An indication in which the length is at least three times the width.

(b) **Nonlinear indication**. An indication of circular or elliptical shape with a length less than three times the width.

(c) **Aligned indication**. Three or more indications in a line, separated by 2 mm or less edge-to-edge.

(d) **Open indication**. An indication visible after removal of the magnetic particles or that can be detected by the use of contrast dye penetrant.

(e) **Non-open indication**. An indication that is not visually detectable after removal of the magnetic particles or that cannot be detected by the use of contrast dye penetrant.

(f) **Relevant indication**. An indication that is caused by a condition or type of discontinuity that requires evaluation. Only indications which have any dimension greater than 1,5 mm are to be considered relevant.

1.8.7 Acceptance standards for defects found by visual or non destructive examinations are to be in accordance with any specific requirements of the approved plan, and with equivalence to any additional requirements of this Chapter. In all cases they are to be to the satisfaction of the Surveyor.

1.8.8 Where required, ultrasonic examination is to be carried out after the forgings have been machined to a condition suitable for this type of examination and after the final heat treatment. Both radial and axial scanning are to be carried out where appropriate for the shape and the dimensions of the forgings being examined. Scanning is to take into account near surface examination. Unless otherwise agreed, examinations are to be carried out by the manufacturer, although Surveyors may request to be present in order to verify that the examination is being carried out in accordance with the agreed procedure.

1.8.9 If the forging is supplied in the black condition for machining at a separate works, the manufacturer is to ensure that a suitable ultrasonic examination is carried out to verify the internal quality of the forging.

1.8.10 In the circumstance detailed in either 1.8.8 or 1.8.9, the manufacturer is to provide the Surveyor with a signed report confirming that ultrasonic examination has been carried out and that such inspection has not revealed any significant internal defects.

1.8.11 Unless otherwise agreed, the accuracy and verification of dimensions are the responsibility of the manufacturer.

1.8.12 In the event of any forging proving defective during subsequent machining or testing, it is to be rejected notwithstanding any previous certification.

1.8.13 When required by the conditions of approval for surface hardened forgings (*see* 1.5.6) additional test samples are to be processed at the same time as the forgings which they represent. These test samples are subsequently to be sectioned in order to determine the hardness, shape and depth of the locally hardened zone and which are to comply with the requirements of the approved specification.

1.9 Rectification of defects

1.9.1 Small surface imperfections may be removed by grinding or by chipping and grinding. Complete elimination of these imperfections is to be proved by magnetic particle or dye penetrant examination (as appropriate to the material). At the discretion of the Surveyor, the resulting shallow grooves or depressions can be accepted, provided that they are blended by grinding.

1.9.2 Repairs by welding are not generally permitted, but special consideration will be given to such repairs where they are of a minor nature and in areas of low working stresses. In such cases, full details of the proposed repair and subsequent inspection procedures are to be submitted for review by the Surveyors prior to the commencement of the proposed rectification. A report and/or sketch detailing the extent and location of all repairs, together with details of the post-weld heat treatment and non-destructive examination are to be provided for record purposes and are to be attached to the certificate.

1.9.3 Repair welding is not permitted for crankshafts or similar rotating components.

1.9.4 Where fabrication welding is involved, *see* 1.2.14, any repair of defects is to be carried out in accordance with the approved welding procedure.

1.9.5 The forging manufacturer is to maintain records of repairs and subsequent inspections traceable to each forging. The records are to be presented to the Surveyor on request.

1.9.6 Non-open indications evaluated as segregation are acceptable.

1.10 Identification

1.10.1 The manufacturer is to adopt a system of identification, which will enable all finished forgings to be traced to the original cast, forging process and heat treatment batch, and the Surveyor is to be given full facilities for so tracing the castings when required.

1.10.2 Forgings are to be clearly marked by the manufacturer in accordance with the requirements of Chapter 1. The following details are to be shown on all forgings which have been accepted:

(a) Identification number, cast number or other marking which will enable the full history of the forging to be traced.
(b) LR or Lloyd's Register and the abbreviated name of LR's local office.
(c) Personal stamp of Surveyor responsible for inspection.
(d) Test pressure, where applicable.
(e) Date of final inspection.

1.10.3 Modified arrangements for the identification of small forgings manufactured in large numbers, as with closed-die forgings may be agreed with the Surveyor.

1.11 Certification of materials

1.11.1 A LR certificate is to be issued, *see* Ch 1,3.1.

1.11.2 The manufacturer is to provide the Surveyor with a written statement giving the following particulars for each forging or batch of forgings which has been accepted:

(a) Purchaser's name and order number.
(b) Description of forgings and steel quality.
(c) Identification number.
(d) Steel-making process, cast number and chemical analysis of ladle samples.
(e) General details of heat treatment.
(f) Results of mechanical tests.
(g) Test pressure, where applicable.

1.11.3 As a minimum, the chemical composition of ladle samples is to include the content of all the elements detailed in the specific requirements.

1.11.4 Where applicable, the manufacturer is also to provide a signed report regarding ultrasonic examination as required by 1.8.8, a report of magnetic particle inspection and a statement and/or sketch detailing all repairs by welding as required by 1.9.2.

1.11.5 When steel is not produced at the works at which it is forged, a certificate is to be supplied by the steelmaker stating the process of manufacture, cast number and the chemical composition of ladle samples. The works at which the steel was produced is to have been approved by LR, *see* 1.4.3.

■ *Section 2* Forgings for ship and other structural applications

2.1 Scope

2.1.1 This Section gives the specific requirements for carbon-manganese steel forgings intended for ship and other structural applications such as rudder stocks, pintles, etc.

2.1.2 Where it is proposed to use an alloy steel, particulars of the chemical composition, mechanical properties and heat treatment are to be submitted for approval, *see* 1.4.3.

2.2 Chemical composition

2.2.1 For forgings to which structural items are to be attached by welding or which are intended for parts of a fabricated component, or are to be weld cladded or may be subject to weld repair in service, the chemical composition of ladle samples is to comply with the following:

Carbon	0,23% max.
Silicon	0,45% max.
Manganese 0,30–1,50% but not less than 3 times the actual carbon content for components which are not given a post-weld heat treatment	
Sulphur	0,035% max.
Phosphorus	0,035% max.
Residual elements:	
Copper	0,30% max.
Chromium	0,30% max.
Molybdenum	0,15% max.
Nickel	0,40% max.
Total	0,85% max.

For samples from forgings, the carbon content is not to exceed 0,26 per cent.

2.2.2 It is recommended that forgings for rudder stocks, pintles and rudder coupling bolts comply with 2.2.1 in order to obtain satisfactory weldability for any future repairs by welding in service.

2.2.3 For forgings not intended for welding the carbon content may be 0,65 per cent max., *see* 3.2.1.

2.3 Heat treatment

2.3.1 Carbon-manganese steel forgings are to be:

(a) fully annealed; or
(b) normalised; or
(c) normalised and tempered at a temperature of not less than 550°C.
(d) quenched and tempered.

2.3.2 Alloy steel forgings are to be quenched and then tempered at a temperature of not less than 550°C. Alternatively, they may be supplied in the normalised and tempered condition, in which case the specified mechanical properties are to be agreed by LR.

2.4 Mechanical tests

2.4.1 At least one tensile specimen is to be taken from each forging or batch of forgings.

2.4.2 Where a forging exceeds both 4 tonnes in mass and 3 m in length, tensile test specimens are to be taken from each end. These limits refer to the 'as forged' mass and length but exclude the test material.

2.4.3 Unless otherwise agreed between the manufacturer and the Surveyor, the test specimens are to be cut in a longitudinal direction.

2.4.4 The results of all tensile tests are to comply with the requirements given in Table 5.2.1 appropriate to the specified minimum tensile strength. Forgings may be supplied to any specified minimum tensile strength within the general limits given in Table 5.2.1, and intermediate values may be obtained by interpolation. *See* 2.4.6 for rudder stocks, pintles, and rudder coupling keys and bolts.

2.4.5 For large forgings, where tensile tests are taken from each end, the variation in tensile strength is not to exceed 70 N/mm^2.

2.4.6 For rudder stocks, pintles, and rudder coupling keys and bolts, the minimum specified yield strength is not to be less than 200 N/mm^2, *see* Table 13.2.4 in Pt 3, Ch 13.

2.4.7 Impact tests are required for rudder stocks to be fitted to vessels which have an ice class notation. The tests are to be carried out at minus 10°C and the average energy value is to be not less than 27J.

2.5 Non-destructive examination

2.5.1 Surface inspections are to be carried out by visual examination and magnetic particle testing (or dye penetrant testing where appropriate).

2.5.2 Surface inspections are to be carried out in the zones I and II as indicated in Fig. 5.2.1.

2.5.3 For the purpose of evaluating indications, the surface is to be divided into reference areas of 225 cm^2. The area is to be taken in the most unfavourable location relative to the indication being evaluated.

2.5.4 The allowable number and size of indications in the reference area is given in Table 5.2.2.

2.5.5 Volumetric inspection is to be carried out by ultrasonic testing using the contact method.

2.5.6 Ultrasonic testing is to be carried out on rudder stocks having a finished diameter of 200 mm or greater.

2.5.7 Ultrasonic testing is to be carried out in the zones I to III as indicated in Fig. 5.2.2. Areas may be upgraded to a higher zone at the discretion of the Surveyor.

Table 5.2.1 Mechanical properties for ship and other structural applications

Steel type	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on $5,65\sqrt{S_o}$ min.%		Reduction of area min. %	
			Long.	Tang.	Long.	Tang.
C and C-Mn	180	360-480	28	20	50	35
	200	400-520	26	19	50	35
	220	440-560	24	18	50	35
	235	470-590	23	17	45	35
	240	480-600	22	16	45	30
	260	520-640	21	15	45	30
	280	560-680	20	14	40	27
	300	600-750	18	13	40	27
	320	640-790	17	12	40	27
	340	680-830	16	12	35	24
	360	720-870	15	11	35	24
	380	760-910	14	10	35	24
Alloy	350	550-570	20	14	50	35
	400	600-750	18	13	50	35
	450	650-800	17	12	50	35

Table 5.2.2 Steel forgings surface inspection

Inspection zone	Maximum number of indications	Type of indication	Maximum number each type	Maximum dimension, mm
I	3	Linear Non-linear Aligned	0, *see* Note 3 0, *see* Note	— 3,0 —
II	10	Linear Non-linear Aligned	3, *see* Note 7 3, *see* Note	3,0 5,0 3,0

NOTE
Linear or aligned indications are not permitted on bolts, which receive a direct fluctuating load, e.g., main bearing bolts, connecting rod bolts, crosshead bearing bolts and cylinder cover bolts.

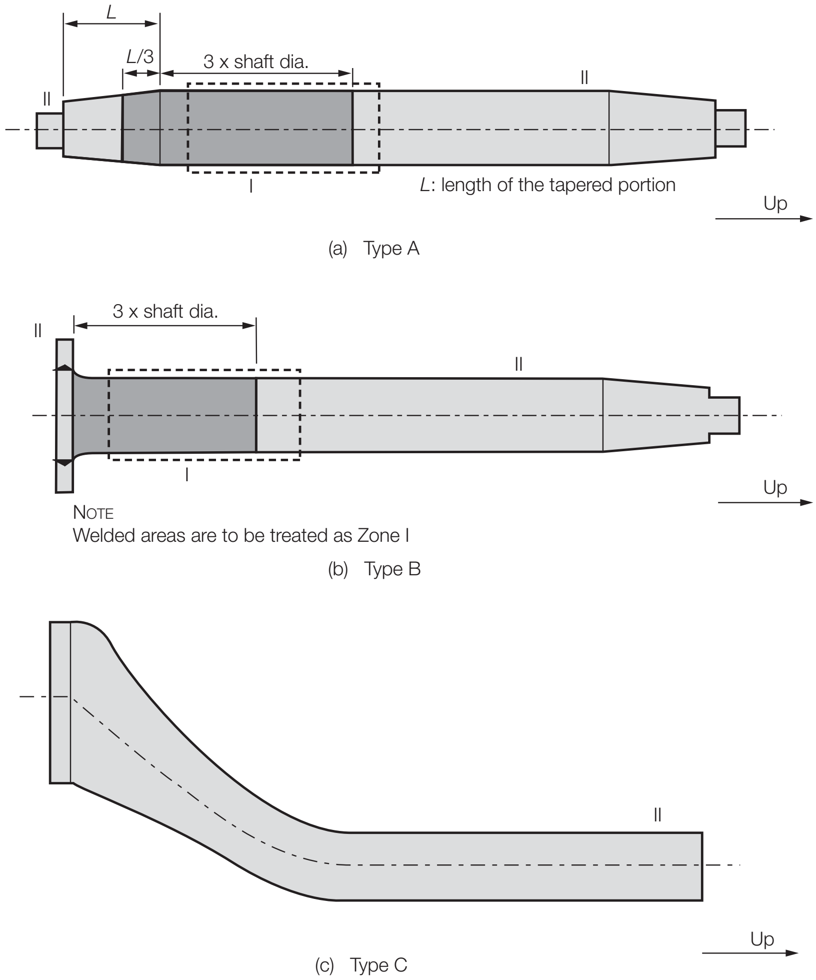
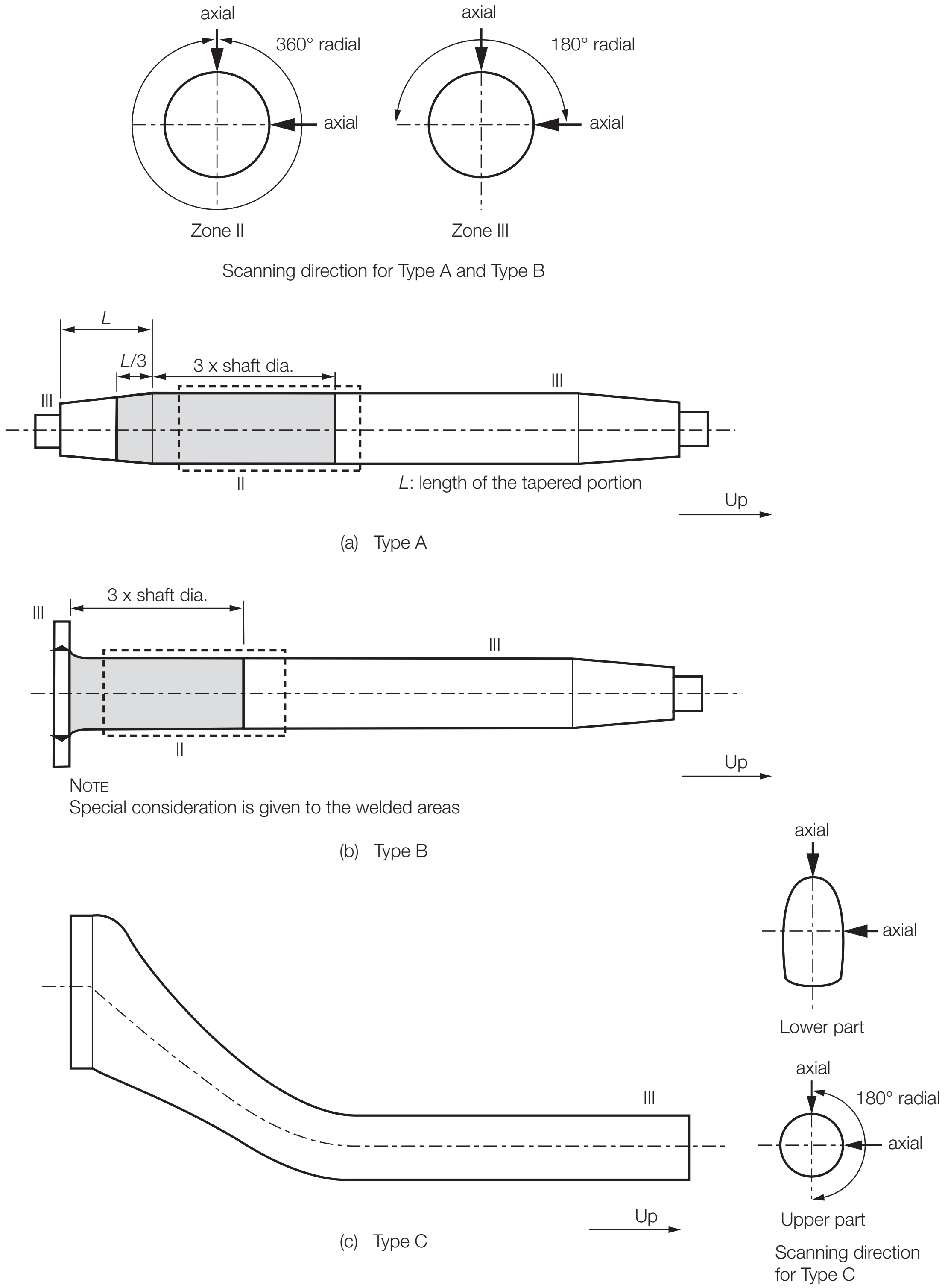


Fig. 5.2.1 Inspection zones for magnetic particle/dye penetrant testing on rudder stocks

2.5.8 Ultrasonic acceptance criteria are shown in Table 5.3.4, alternatively *see* Ch 1,5.



NOTE
Axial scan from end face also required for Type A and Type B

Fig. 5.2.2 Inspection zones for ultrasonic testing on rudder stocks

Section 3
Forgings for shafting and machinery

3.1 Scope

3.1.1 Detailed in this Section are the requirements for carbon-manganese steel forgings for shafting and other items of machinery which are not within the scope of Sections 4 to 8.

3.1.2 Where it is proposed to use alloy steel forgings, particulars of the chemical composition, mechanical properties and heat treatment are to be submitted for approval. For main propulsion shafting in alloy steels, the specified minimum tensile strength is not to exceed 800 N/mm^2 (800–950 N/mm^2 acceptance range) and for other forgings is not to exceed 1100 N/mm^2 (1100–1300 N/mm^2 acceptance range).

3.2 Chemical composition

3.2.1 The chemical composition of ladle samples for carbon and carbon-manganese steels is to comply with the following overall limits:

Carbon	0,65% max.
Silicon	0,45% max.
Manganese	0,30–1,50%
Sulphur	0,035% max.
Phosphorus	0,035% max.
Residual elements:	
Copper	0,30% max.
Chromium	0,30% max.
Molybdenum	0,15% max.
Nickel	0,40% max.
Total	0,85% max.

3.2.2 For alloy steels, *see* 1.4.3.

3.2.3 For forgings to which structural items are to be attached by welding, or which are intended for parts of a fabricated component, are to be of weldable quality, *see* 2.2.1.

3.3 Heat treatment

3.3.1 Forgings are to be:
(a) fully annealed; or
(b) normalised; or
(c) normalised and tempered; or
(d) quenched and tempered.
The tempering temperature is to be not less than 550°C.

3.4 Mechanical tests

3.4.1 At least one tensile test is to be made on each forging, or each batch of forgings. Impact tests are not required except on screwshafts for ice service, *see* 3.4.12.

3.4.2 Where a forging exceeds both 4 tonnes in mass and 3 m in length, a tensile test is to be taken from each end. These limits refer to the 'as forged' mass and length but exclude the test material.

3.4.3 A batch testing procedure may be used for hot rolled bars not exceeding 250 mm diameter, which are intended for the manufacture (by machining operations only) of straight shafting, bolts, studs and other machinery components of similar shape. A batch is to consist of either:
(a) material from the same piece provided that where this is cut into individual lengths, these are all heat treated together in the same furnace; or
(b) bars of the same diameter and cast, heat treated together in the same furnace and with a total mass not exceeding 2,5 tonnes.

3.4.4 The test specimens are to be taken in the longitudinal direction but, at the discretion of the manufacturer and if agreed by the Surveyor, alternative directions or positions as shown in Figs. 5.3.1 to 5.3.3 may be used.

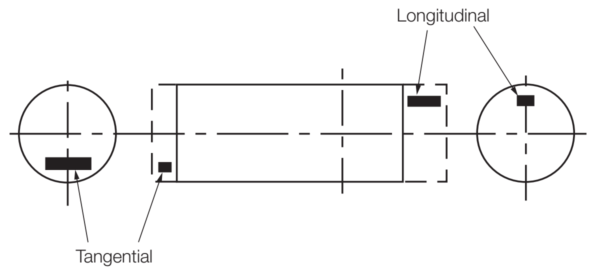


Fig. 5.3.1
Directions and positions of test specimens

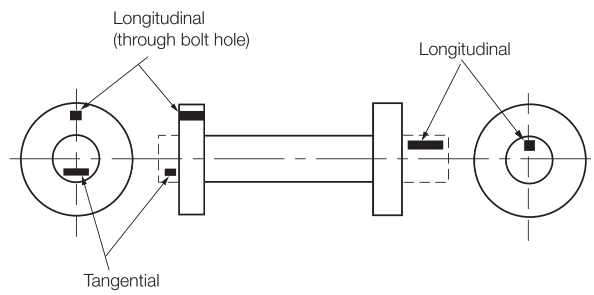


Fig. 5.3.2
Directions and positions of test specimens

3.4.5 For carbon-manganese steels, Table 5.3.1 gives the minimum requirements for yield stress, elongation and reduction of area, corresponding to different strength levels, but it is not intended that these should necessarily be regarded as specific grades. Intermediate values for other specified minimum tensile strengths should be calculated by interpolation.

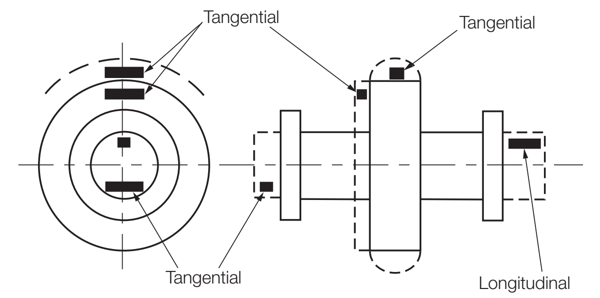


Fig. 5.3.3
Directions and positions of test specimens

3.4.6 Forgings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Table 5.3.1, except that for main propulsion shafting forgings the specified minimum tensile strength is to be not less than 400 N/mm^2 (400–520 N/mm^2 acceptance range) and not greater than 600 N/mm^2 (600–750 N/mm^2 acceptance range) *see* shaded area of Table 5.3.1.

3.4.7 The results of all tensile tests are to comply with the requirements given in Table 5.3.1 appropriate to the specified minimum tensile strength.

3.4.8 The minimum requirements for yield stress, elongation and reduction of area, corresponding to different strength levels in alloy steel forgings are given in Table 5.3.2.

Table 5.3.1 Mechanical properties for acceptance purposes: carbon and carbon-manganese steel forgings for machinery and shafting

Tensile strength N/mm^2	Yield stress N/mm^2	Elongation on $5{,}65\sqrt{S_o}$ min.%		Reduction of area min. %	
		Long.	Tang.	Long.	Tang.
360–480	180	28	20	50	35
400–520	200	26	19	50	35
440–560	220	24	18	50	35
470–590	235	23	17	45	35
480–600	240	22	16	45	30
520–640	260	21	15	45	30
560–680	280	20	14	40	27
600–750	300	18	13	40	27
640–790	320	17	12	40	27
680–830	340	16	12	35	24
700–850 [2]	350	15	11	35	24
720–870 [2]	360	15	11	35	24
760–910 [2]	380	14	10	35	24

NOTES
1. For main propulsion shafting forgings, the specified minimum tensile strength is to be between 400 and 600 N/mm^2 (shaded area of Table) *see* 3.4.6.
2. Where the specified minimum tensile strength exceeds 700 N/mm^2, forgings are to be supplied only in the quenched and tempered condition.

Table 5.3.2 Mechanical properties for acceptance purposes: alloy steel forgings for machinery and shafting

Tensile strength N/mm^2	Yield stress N/mm^2	Elongation on $5{,}65\sqrt{S_o}$ min.%		Reduction of area min. %	
		Long.	Tang.	Long.	Tang.
600–750	420	18	14	50	35
650–-800	450	17	13	50	35
700–850	480	16	12	45	30
750–900	530	15	11	45	30
800–950	580	14	10	40	27
850–1000	630	13	9	40	27
900–1100	690	13	9	40	27
950–1150	750	12	8	35	24
1000–1200	810	12	8	35	24
1050–1250	870	11	7	35	24
1100–1300	930	11	7	35	24

NOTE
For main propulsion shafting forgings, the minimum specified tensile strength is not to exceed 800 N/mm^2, *see* 3.4.9 (shaded area of Table).

3.4.9 Forgings in alloy steels may be supplied to any specified minimum tensile strength selected within the general limits detailed in Table 5.3.2, and minimum yield stress, elongation and reduction of area, obtained by interpolation, except that for main propulsion shafting forgings the specified minimum tensile strength is not to exceed 800 N/mm^2 (800–950 N/mm^2 acceptance range) *see* shaded area of Table 5.3.2.

3.4.10 The results of all tensile tests are to comply with the requirements given in Table 5.3.2 appropriate to the specified minimum tensile strength.

3.4.11 Where more than one tensile test is taken from a forging, the variation in tensile strength is not to exceed the following:

Specified minimum tensile strength N/mm^2	Difference in tensile strength N/mm^2
<600	70
≥600 < 900	100
≥900	120

3.4.12 For screwshafts intended for ships with the notation **Ice Class 1AS** or **1A** and where the connection between the propeller and the screwshaft is by means of a key, a set of three Charpy V-notch impact tests (longitudinal test) is to be made on material from the propeller end of each shaft. The tests are to be carried out at –10°C and the average energy value is to be not less than 20 J.

3.5 Non-destructive examination

3.5.1 Magnetic particle or dye penetrant testing (where appropriate) is to be carried out on forgings for main propulsion shafting (including propeller shafts, intermediate shafts, and thrust shafts with minimum diameter not less than 100 mm), on all connecting rod forgings and on the following components when they are intended for engines having a bore diameter larger than 400 mm:

- Cylinder covers
- Piston crowns
- Piston rods
- Tie rods
- Gear wheels for camshaft drives
- Bolts and studs for:
  - Cylinder covers
  - Crossheads
  - Main bearings
  - Connecting rod bearings
  - Propeller blade fastening bolts
  - Crankpin bolts
  - Tie rod bolts
  - Additionally, bolts for engine bore diameters of less than 400 mm but having a minimum diameter 50 mm or greater (which are subjected to dynamic stress), are also to be subjected to surface examinations.

3.5.2 The areas to be tested by magnetic particle or dye penetrate testing are shown in Fig. 5.3.4 and Fig. 5.3.5. Areas of other components not shown in these figures are to be agreed with the Surveyor. For tie rods, only threaded portions and the adjacent material over a length equal to that of the thread need be tested.

3.5.3 Surface inspection acceptance criteria are to be in accordance with 2.5. Other acceptance criteria may be applied, providing they meet these minimum criteria, and are to the satisfaction of the Surveyor.

3.5.4 Ultrasonic testing is to be carried out in accordance with 2.5 on the following items:

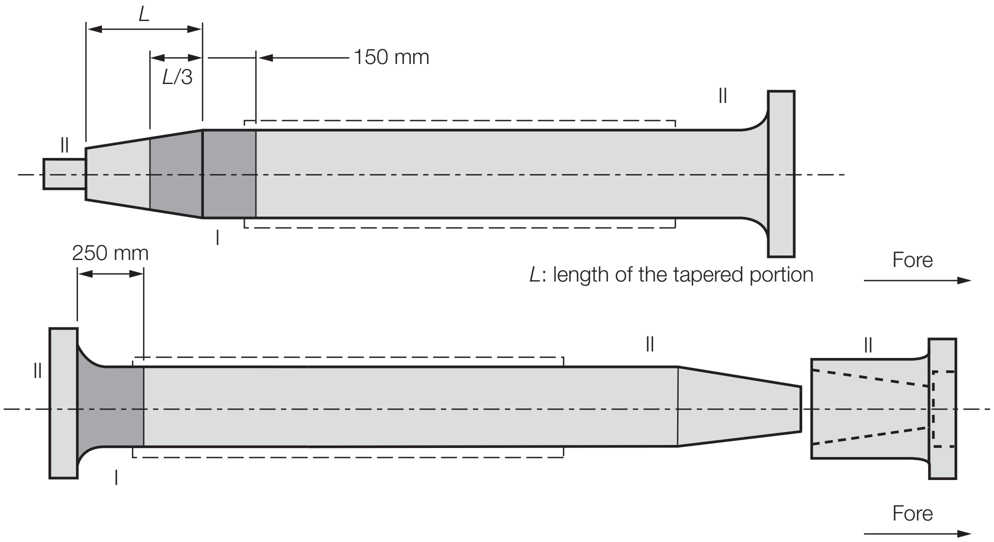
(a) Shafts having a finished diameter of 200 mm or larger when intended for main propulsion or other essential services.

(b) All piston crowns and cylinder covers.

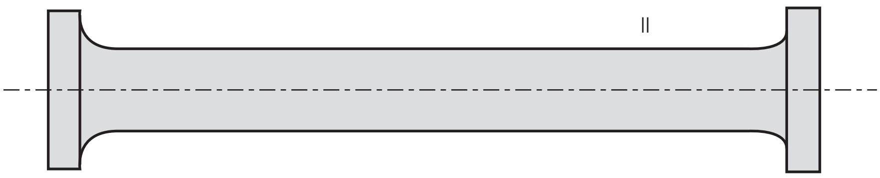
(c) Piston rods and connecting rods for engines having a bore diameter greater than 400 mm.

The areas to be tested are shown in Fig. 5.3.6 and Fig. 5.3.7. Areas of other components not shown in these drawings are to be agreed with the Surveyor.

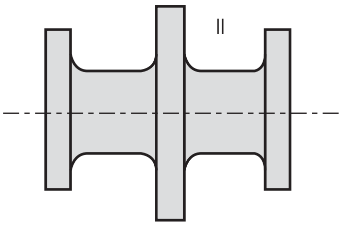
3.5.5 Ultrasonic acceptance criteria are shown in Table 5.3.3. Other acceptance criteria may be applied, providing they meet these minimum criteria, and are to the satisfaction of the Surveyor.



(a) Propeller shaft



(b) Intermediate shaft



(c) Thrust shaft

NOTE
For propeller shaft, intermediate shafts and thrust shafts, all areas with stress raisers such as radial holes, slots and key ways are to be treated as Zone I.

Fig. 5.3.4 Zones for magnetic particle/dye penetrant testing on machinery components

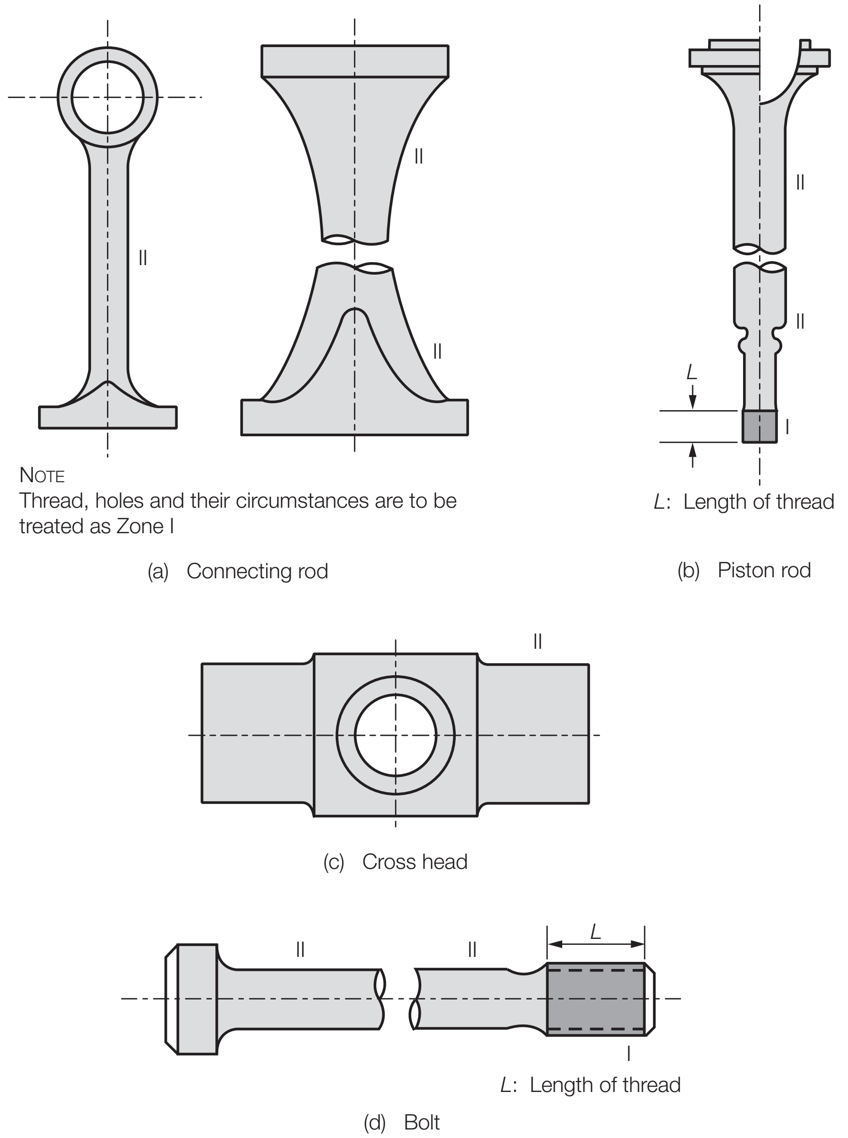
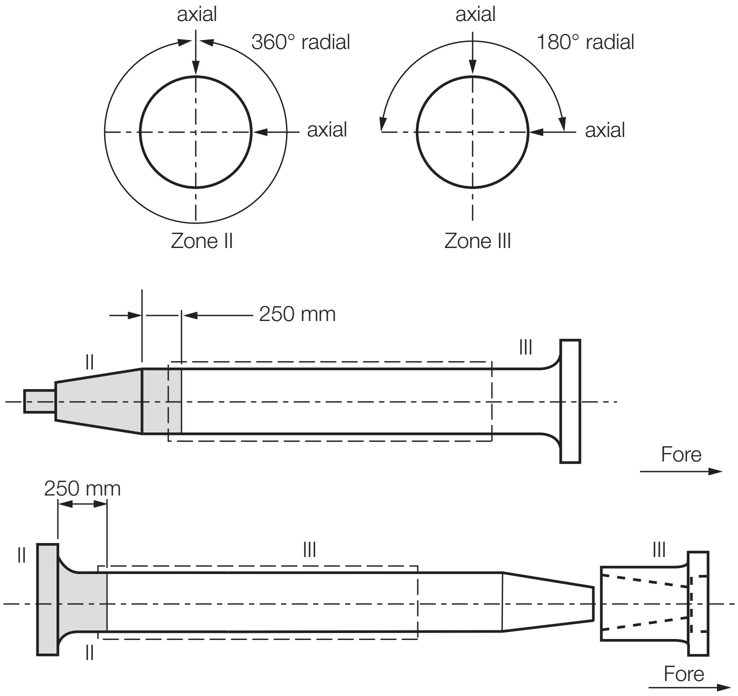
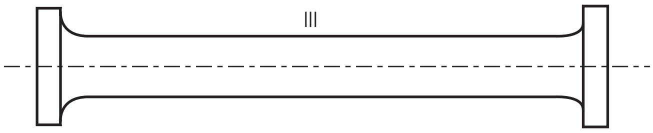


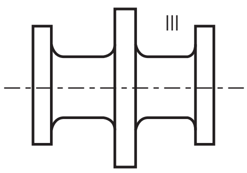
Fig. 5.3.5 Zones for magnetic particle/dye penetrant testing on machinery components



(a) Propeller shaft



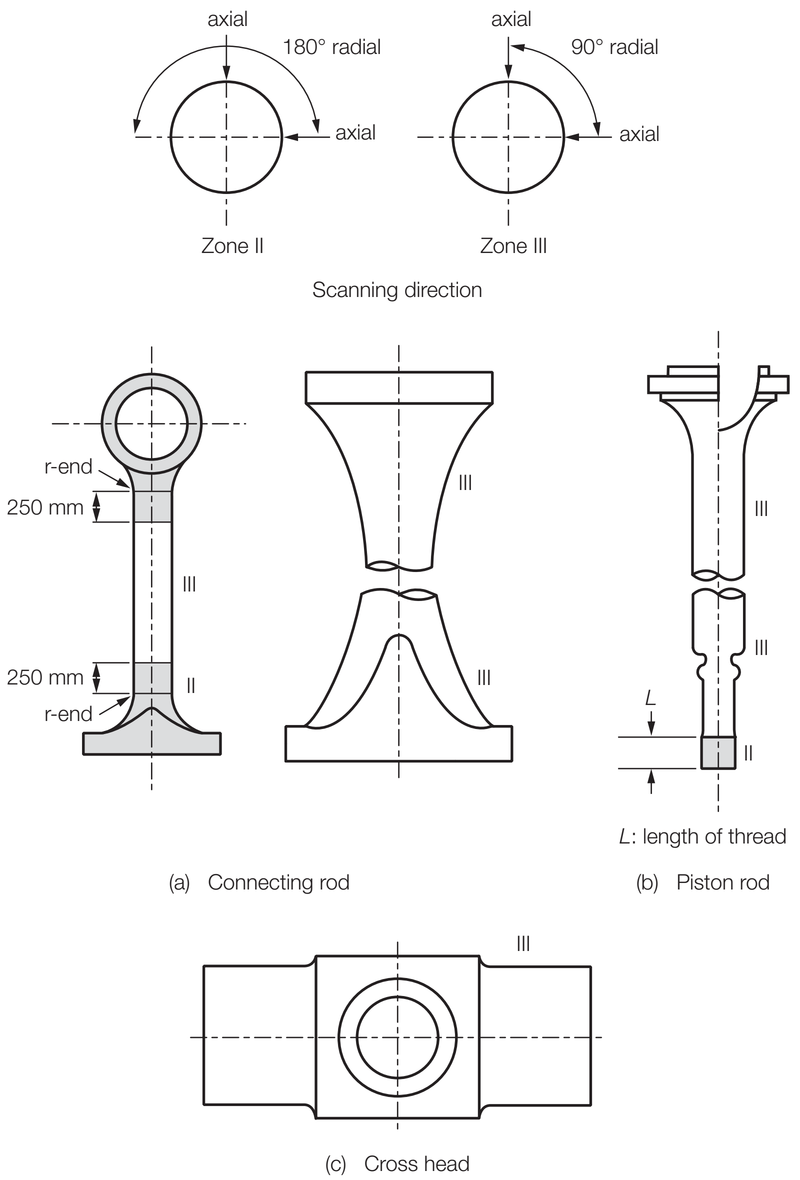
(b) Intermediate shaft



(c) Thrust shaft

NOTES
1. For hollow shafts, 360° radial scanning applies to Zone III
2. Circumferences of the bolt holes in the flanges are to be treated as Zone II
3. Axial scan from end face also required

Fig. 5.3.6 Zones for ultrasonic testing on shafts



NOTE
Axial scan from end face also required

Fig. 5.3.7 Zones for ultrasonic testing on machinery components

Table 5.3.3 Acceptance criteria for ultrasonic testing

Type of forging	Zone	Allowable disc shape according to Distance Gain Size (DGS), *see* Note 1, mm	Allowable length of indication, mm *see* Note 2
Propeller shaft Intermediate shaft	II	Outer $d \leq 2$ Inner $d \leq 4$	≤10 ≤15
Thrust shaft Rudder stock	III	Outer $d \leq 3$ Inner $d \leq 6$	≤10 ≤15
Connecting rod Piston rod	II	$d \leq 2$	≤10
	III	$d \leq 4$	≤10

NOTES
1. Outer part means the part beyond one third of the shaft radius from the centre. The inner part means the remaining core area.
2. For accumulations of two or more isolated indications which are subjected to registration, the minimum distance between two neighbouring indications is to be at least the length of the larger indication.

■ *Section 4* Forgings for crankshafts

4.1 Scope

4.1.1 The specific requirements for solid forged crankshafts and forgings for use in the construction of fully built and semi-built crankshafts are detailed in this Section.

4.1.2 Where it is proposed to use alloy steel forgings, particulars of the chemical composition (*see* 1.4.3), heat treatment and mechanical properties are to be submitted for approval. The specified minimum tensile strength is not to exceed 1000 N/mm^2 (1000–1200 N/mm^2 acceptance range).

4.2 Manufacture

4.2.1 For closed die and continuous grain flow crankshafts forgings, where an allowance is given for design purposes, full details of the proposed method of manufacture are to be submitted for approval. In such cases, tests will be required to demonstrate that a satisfactory structure and grain flow are obtained. The number and positions of test specimens are to be agreed with LR.

4.2.2 For the manufacture of welded crankshafts, approval is required for the welding procedure.

4.2.3 For combined crankweb and pin forgings, the proposed method of forging is to be submitted for approval. It is recommended that these forgings be made by a folding method. Other methods which can be shown to produce sound forgings with satisfactory mechanical properties will be considered, but where the gapping method is used for cranks having a pin diameter exceeding 510 mm this will only be accepted provided that an upsetting operation is included in the manufacturing sequence. In general, the amount of work during the upsetting operation is to be such that the reduction in the original length of the ingot (after discard) or bloom is not less than 50 per cent.

4.2.4 Where crankwebs are flame cut from forged or rolled slabs, the procedure used is to be in accordance with 1.2.13, and additionally, unless specially agreed, a depth of at least 7,5 mm is to be removed by machining from all flame-cut surfaces.

4.3 Chemical composition

4.3.1 The chemical composition of ladle samples is to comply with 3.2.1 for carbon and carbon-manganese steels and 1.4.3 for alloy steels.

4.3.2 For alloy steel forgings which are to be nitrided, the phosphorus or sulphur contents are not to exceed 0,02 per cent.

4.4 Heat treatment

4.4.1 For forgings in all types of steels, heat treatment is to be either:
(a) normalising and tempering, or
(b) quenching and tempering.
The temperature used for tempering is to be not less than 550°C.

4.4.2 Where it is proposed to surface harden crankshaft forgings by nitriding or induction hardening, full details of the proposed procedure are to be submitted as required by 1.5.6.

4.5 Mechanical tests

4.5.1 At least one tensile test specimen is to be taken from each forging.

4.5.2 For solid forged crankshafts, tests are to be taken in the longitudinal direction from the coupling end of each forging (test position A in Fig. 5.4.1). Where the mass, as heat treated but excluding test material, exceeds 3 tonnes, a second set of tests is to be taken from the end opposite the coupling, in addition (test position B in Fig. 5.4.1). Where the crankthrows are formed by machining or flame cutting, the second set of tests is to be taken in a tangential direction from material removed from the crankthrow at the end opposite the coupling (test position C in Fig. 5.4.1).For continuous grain flow (CGF) crankshaft forgings, where insufficient material exists for a second longitudinal test, the second set of tests may be taken in a tangential direction from the crankthrow (test position C in Fig. 5.4.2).

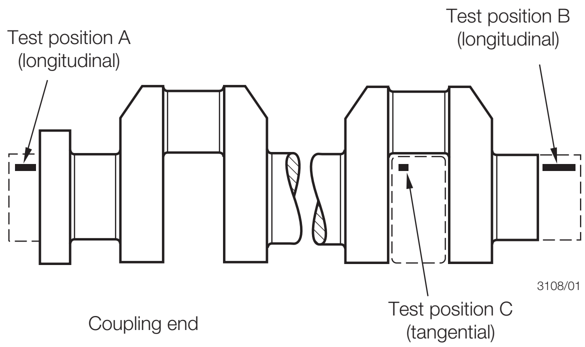


Fig. 5.4.1 Solid forged crankshaft

4.5.3 The number and position of test specimens from combined crankweb and pin forgings are to be in accordance with the requirements of the approved method of manufacture.

4.5.4 For other crankshaft forgings, tests are to be taken as detailed in Section 3, except that for crankwebs the test specimens are to be cut in a tangential direction.

4.5.5 As an alternative to 4.5.2, small solid forged crankshafts may be batch tested in accordance with 1.6.4, provided that, in addition, hardness tests are carried out on each forging.

4.5.6 Tables 5.4.1 to 5.4.3 give the minimum requirements for yield stress and elongation corresponding to different strength levels, but it is not intended that these should necessarily be regarded as specific grades. The strength levels have been given in multiples of 40 N/mm^2, or 50 N/mm^2 in the case of alloy steels, to facilitate interpolation for intermediate values of specified minimum tensile strength.

Table 5.4.1 Mechanical properties for acceptance purposes: carbon-manganese steel forgings for crankshafts

Tensile strength N/mm^2	Yield stress N/mm^2 minimum	Elongation on $5{,}65\sqrt{S_o}$ % minimum		Hardness Brinell
		Long.	Tang.	
400–520	200	26	19	110–150
440–560	220	24	18	125–160
480–600	240	22	16	135–175
520–640	260	21	15	150–185
560–680	280	20	14	160–200
600–750	300	18	13	175–215
640–790	320	17	12	185–230
680–830	340	16	12	200–240
720–870	350	15	11	210–250
760–910	380	14	18	225–265
Intermediate values may be obtained by interpolation.				

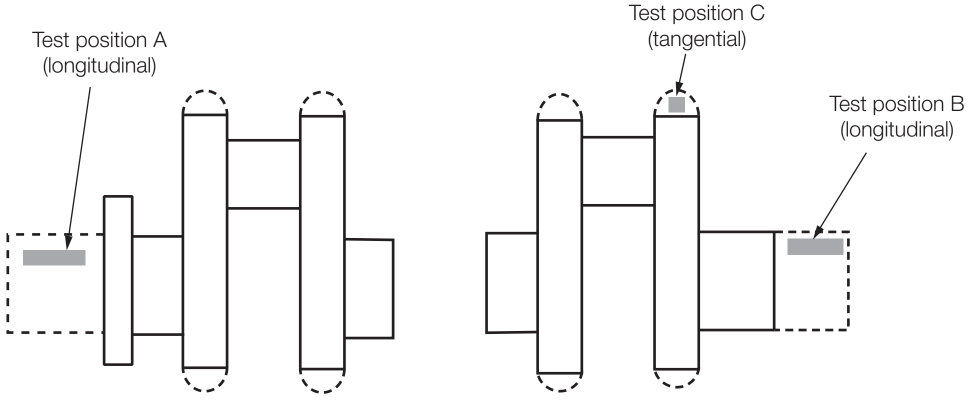


Fig. 5.4.2 CGF Crankshaft

Table 5.4.2 **Mechanical properties for acceptance purposes: alloy steel forgings for crankshafts – Normalised and tempered**

Tensile strength N/mm^2	Yield stress N/mm^2 minimum	Elongation on $5,65\sqrt{S_o}$ % minimum		Hardness Brinell
		Long.	Tang.	
600–750	330	18	14	175–215
650–800	355	17	13	190–235
700–850	380	16	12	205–245
750–900	405	15	11	215–260
800–950	430	14	10	235–275
Intermediate values may be obtained by interpolation.				

Table 5.4.3 **Mechanical properties for acceptance purposes: alloy steel forgings for crankshafts – Quenched and tempered**

Tensile strength N/mm^2	Yield stress N/mm^2 minimum	Elongation on $5,65\sqrt{S_o}$ % minimum		Hardness Brinell
		Long.	Tang.	
600–750	420	18	14	175–215
650–800	450	17	13	190–235
700–850	480	16	12	205–245
750–900	530	15	11	215–260
800–950	590	14	10	235–275
850–1000	640	13	9	245–290
900–1100	690	13	9	260–320
950–1150	750	12	8	275–340
1000–1200	810	12	8	290–365
Intermediate values may be obtained by interpolation.				

4.5.7 Forgings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Tables 5.4.1 to 5.4.3.

4.5.8 The results of all tensile tests are to comply with the requirements of Table 5.4.1, 5.4.2 or 5.4.3 appropriate to the specified minimum tensile strength.

4.5.9 Where more than one tensile test is taken from a forging, the variation in tensile strength is not to exceed the following:

Specified minimum tensile strength N/mm^2	Difference in tensile strength N/mm^2
<600	70
≥600 <900	100
≥900	120

4.5.10 For small crankshaft forgings which have been batch tested, the hardness values are to be not less than those given in Tables 5.4.1 to 5.4.3, as appropriate. The variation in hardness in each batch is to comply with the following:

Specified minimum tensile strength (N/mm^2)	Difference in hardness (Brinell number)
<600	not more than 25
≥600 <900	not more than 35
≥900	not more than 42

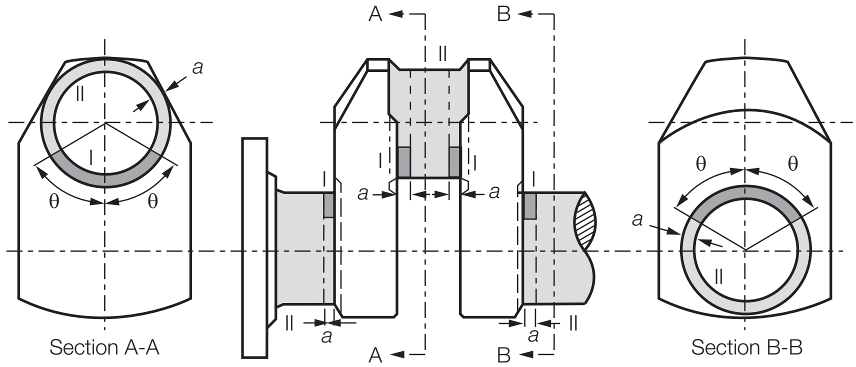
4.6 Non-destructive examination

4.6.1 Magnetic particle or dye penetrant testing as detailed in 1.8.5 and 2.5 is to be carried out on all forgings for crankshafts. Where applicable, this is to include all surfaces which have been flame-cut, but not subsequently machined during manufacture. Particular attention is to be given to the testing of the pins, journals and associated fillet radii of solid forged crankshafts and to the pins and fillet radii of combined web and pin forgings. The extent of testing is shown in Fig. 5.4.3.

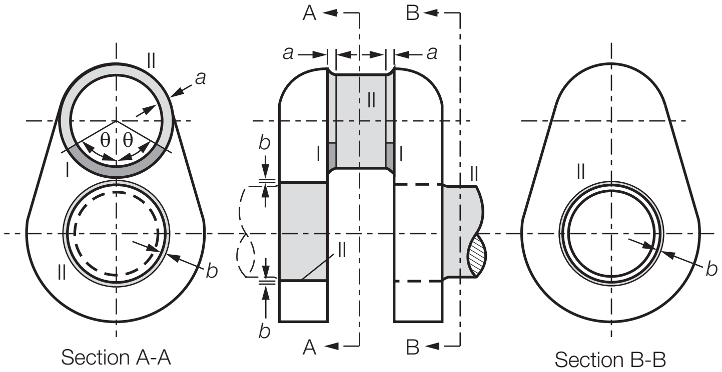
4.6.2 The manufacturer is to carry out an ultrasonic examination of all forgings as detailed in 1.8.8 and 2.5, except that for closed-die forgings this examination may, subject to approval, be confined to the initial production and to subsequent occasional checks. The extent of ultrasonic testing is shown in Fig. 5.4.4.

4.6.3 Surface inspection acceptance criteria are to be in accordance with 2.5 and with Table 5.4.4. Other acceptance criteria may be applied, providing they meet these minimum criteria, and is to the satisfaction of the Surveyor.

4.6.4 Ultrasonic acceptance criteria are shown in Table 5.4.5. Other acceptance criteria may be applied, providing they meet these minimum criteria, and is to the satisfaction of the Surveyor.



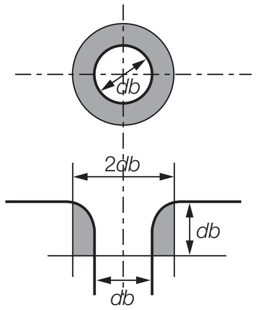
(a) Soild crankshaft



(b) Semi built-up crankshaft

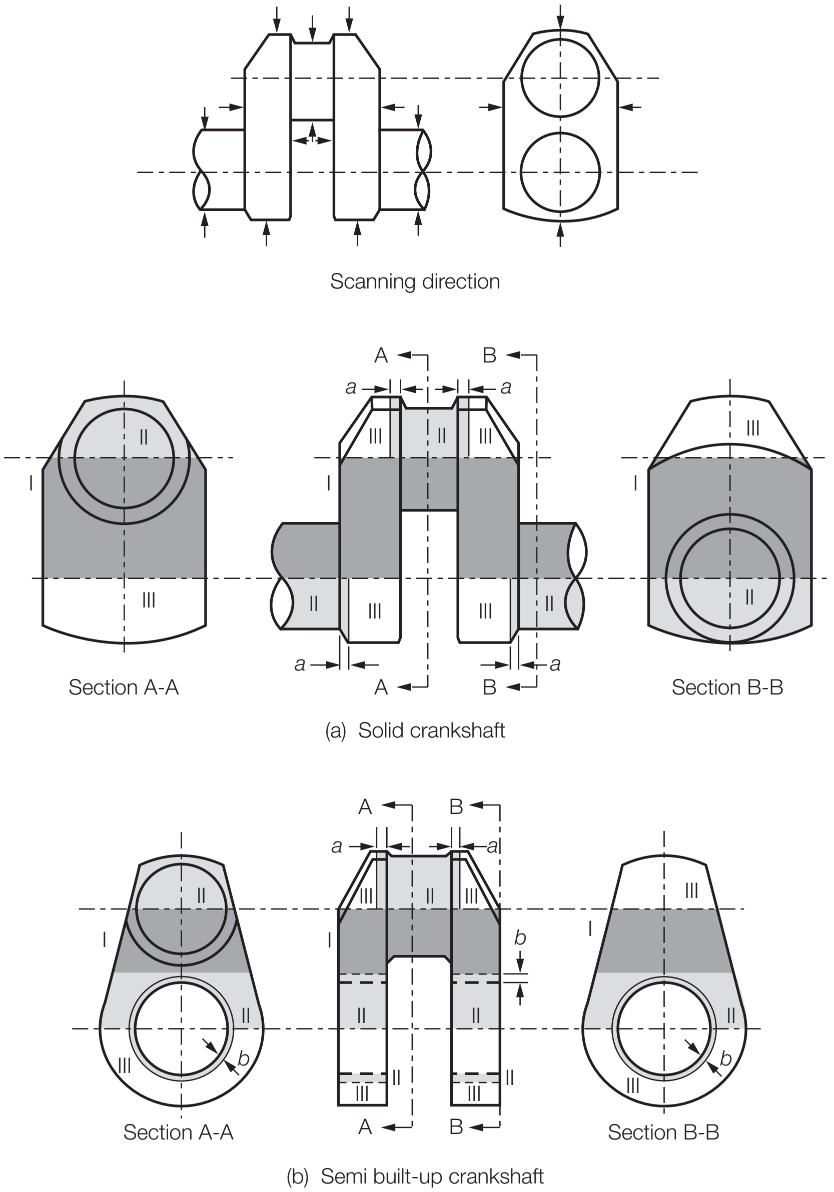
Notes

1. Where the crankpin or journal has oil holes, the circumferential surfaces of the oil are to be treated as Zone I, (*see* the figure on the right)
2. In the above figures:
   θ = 60°
   a = 1,5*r*
   b = 0,05*d* (: circumferential surfaces of shrinkage fit)
   where
   r : fillet radius
   d : journal diameter
3. Identification of the Zones:
   : Zone I
   : Zone II



db: Oil hole bore diameter

Fig. 5.4.3 Zones for magnetic particle/dye penetrant testing on crankshafts



NOTES
1. In the above figures:
   a = 0,1*d* or 25 mm, whichever is greater
   b = 0,05*d* or 25 mm, whichever is greater (: circumstances of shrinkage fit)
   where
   d : pin or journal diameter
2. The mid third area of crank pins and/or journals within a raduis of 0,25*d* between the webs may generally be coordinated to Zone II
3. Identification of the Zones:
   : Zone I
   : Zone II
   : Zone III

Fig. 5.4.4 Zones for ultrasonic testing on crankshafts

Table 5.4.4 Surface inspection acceptance for crankshaft forgings – Allowable number and size of indications in a reference area of 225 cm^2

Inspection zone	Maximum number of indication	Type of indication	Maximum number each type	Maximum dimension of single indication, mm
I Critical fillet area	0	Linear Non-linear Aligned	0 0 0	— — —
II Important fillet area	3	Linear Non-linear Aligned	0 3 0	— 3,0 —
III Journal surfaces	3	Linear Non-linear Aligned	0 3 0	— 5,0 —

Table 5.4.5 Ultrasonic acceptance criteria for crankshafts

Type of forging	Zone	Allowable disc shape according to Distance Gain Size (DGS), mm	Allowable length of indication, mm *see* Note
Crank shaft	I II III	$d \leq 2,0$ $d \leq 3,0$ $d \leq 4,0$	— ≤10 ≤15
NOTE For accumulations of two or more isolated indications which are subjected to registration, the minimum distance between two neighbouring indications is to be at least the length of the larger indication. This applies to the distance in axial direction as to the distance in depth. Isolated indications with less distance are to be determined as one single indication.			

■ *Section 5*
Forgings for gearing

5.1 Scope

5.1.1 Provision is made in this Section for carbon-manganese and alloy steel forgings intended for use in the construction of gearing for main propulsion and for driving electric generators.

5.1.2 Gear wheel and rim forgings with a specified minimum tensile strength not exceeding 760 N/mm^2 (760–910 N/mm^2 acceptance range) may be made in carbon-manganese steel. Gear wheel or rim forgings where the specified minimum tensile strength is in excess of 760 N/mm^2, and all pinion or pinion sleeve forgings, are to be made in a suitable alloy steel. Specifications for alloy steel components and for quill shafts, giving chemical composition, heat treatment and mechanical properties, are to be submitted for approval.

5.1.3 Forgings for flexible couplings, quill shafts and gear wheel shafts are to comply with the requirements of Section 3.

5.1.4 Manufacturers' test certificates for forgings may be accepted where the transmitted power does not exceed 220 kW (300 shp) for main propulsion and 100 kW (150 shp) for auxiliary drives.

5.2 Manufacture

5.2.1 All forgings are to be made with sufficient material to allow an adequate machining allowance on all surfaces for the removal of unsound or decarburised material.

5.2.2 The hardenability of the forged material is to be checked at random intervals using an end quench test complying with a National or International Standard.

5.2.3 The grain size is to be checked on a random basis in accordance with the testing and reporting procedures of ASTM E 112, or an equivalent National Standard, and is to be within the range 5 to 8.

5.2.4 The microstructure of the hardened case is to be mainly martensite, with a maximum content of 15 per cent of retained austenite.

5.3 Chemical composition

5.3.1 The chemical composition of ladle samples is to comply with 3.2.1. for carbon and carbon-manganese steels and 1.4.3 for alloy steels.

5.4 Heat treatment

5.4.1 Except as provided in 5.4.4 and 5.4.5, forgings may be either normalised and tempered or quenched and tempered in accordance with the approved specification. The tempering temperature is to be not less than 550°C.

5.4.2 Where forgings are machined prior to heat treatment, the allowance left for final machining is to be sufficient to remove the decarburised surface material, taking into account any bending or distortion which may occur.

5.4.3 When the teeth of a pinion or gear wheel are to be surface hardened, i.e, carburised, nitrided or induction hardened, the proposed specification together with details of the process and practice are to be submitted for approval. For purposes of initial approval, the gear manufacturer is required to demonstrate by test that the surface hardening of the teeth is uniform and of the required depth and that it does not impair the soundness and quality of the steel.

5.4.4 Where induction hardening of nitriding is to be carried out after machining of the gear teeth, the forgings are to be heat treated at an appropriate stage to a condition suitable for this subsequent surface hardening.

5.4.5 Forgings for gears which are to be carburised after final machining are to be supplied in either the fully annealed or the normalised and tempered condition, suitable for subsequent machining and carburising.

5.5 Mechanical tests for through hardened, induction hardened or nitrided forgings

5.5.1 At least one tensile test specimen is to be taken from each forging in carbon or carbon-manganese steel, and at least one tensile test specimen from forgings in alloy steel. Sufficient test material is to be provided for this purpose and the test specimens are to be taken as follows:

(a) For pinion forgings where the finished diameter of the toothed portion exceeds 200 mm, tests are to be taken in a tangential direction and adjacent to the toothed portion (test position B in Fig. 5.5.1). Where the dimensions preclude the preparation of tests from this position, tests in a tangential direction are to be taken from the end of the journal (test position C in Fig. 5.5.1). If, however, the journal diameter is 200 mm or less, tests are to be taken in a longitudinal direction (test position A in Fig. 5.5.1). Where the finished length of the toothed portion exceeds 1250 mm, tests are to be taken from each end.

(b) For small pinion forgings where the finished diameter of the toothed portion is 200 mm or less, tests are to be taken in a longitudinal direction (test position A in Fig. 5.5.1).

(c) For gear wheel forgings, tests are to be taken in a tangential direction (from one of the test positions B in Fig. 5.5.2).

(d) For gear wheel rim forgings, tests are to be taken in a tangential direction (from one of the test positions A in Fig. 5.5.3). Where the finished diameter exceeds 2500 mm or the mass (as heat treated but excluding test material) exceeds 3 tonnes, tests are to be taken from two diametrically opposite positions (test positions A in Fig. 5.5.3).

(e) For pinion sleeve forgings, tests are to be taken in a tangential direction (from one of the test positions C in Fig. 5.5.4). Where the finished length exceeds 1250 mm, tests are to be taken from each end.

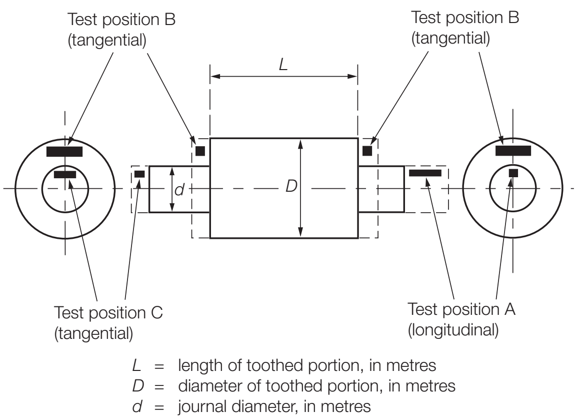


Fig. 5.5.1 Test positions for forgings for gearing

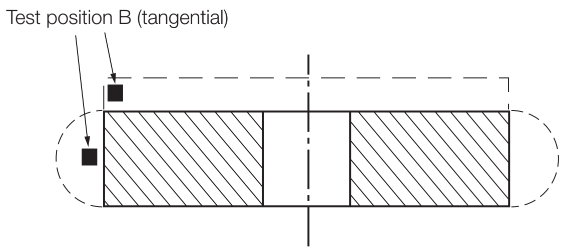


Fig. 5.5.2 Test position B

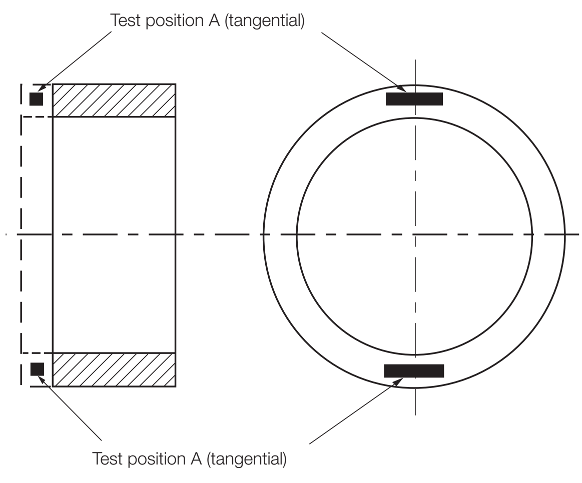


Fig. 5.5.3 Test position A

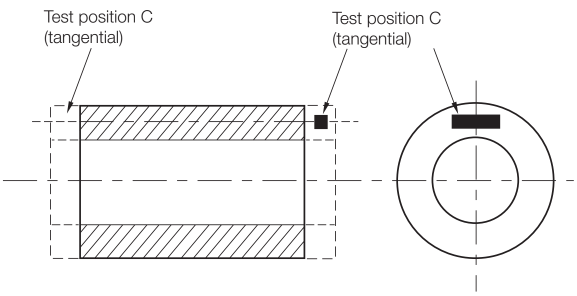


Fig. 5.5.4 Test position C

5.5.2 As an alternative to 5.5.1, small forgings may be batch tested in accordance with 1.6.4 provided that, in addition, hardness tests are carried out on each forging.

5.5.3 Tables 5.5.1 to 5.5.3 give the minimum requirements for yield stress and elongation corresponding to different strength levels, but it is not intended that these should necessarily be regarded as specific grades. The strength levels have been given in multiples of 40 N/mm^2, or 50 N/mm^2 in the case of alloy steels, to facilitate interpolation for intermediate values of specified minimum tensile strength.

Table 5.5.1 Mechanical properties for acceptance purposes: carbon-manganese steels for gear wheel and rim forgings

Tensile strength N/mm^2 (*see* Note)	Yield stress N/mm^2 minimum	Elongation on $5,65\sqrt{S_o}$ % minimum		Hardness Brinell
		Rims	Wheels	
400–520	200	26	22	110–150
440–560	220	24	21	125–160
480–600	240	22	19	135–175
520–640	260	21	18	150–185
560–680	280	20	17	160–200
600–750	300	18	15	175–215
640–790	320	17	14	185–230
680–830	340	16	14	200–240
720–870	360	15	13	210–250
760– 910	380	14	12	225–265
Intermediate values may be obtained by interpolation.				
NOTE When the specified minimum tensile strength exceeds 700 N/mm^2 forgings are to be supplied only in the quenched and tempered condition.				

5.5.4 Forgings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Tables 5.5.1 to 5.5.3.

5.5.5 The results of all tensile tests are to comply with the requirements of Table 5.5.1, 5.5.2 or 5.5.3, appropriate to the specified minimum tensile strength. Unless otherwise agreed, the specified minimum tensile strength is to be not less than 800 N/mm^2 (800–950 N/mm^2 acceptance range) for induction hardened or nitrided gear forgings.

Table 5.5.2 Mechanical properties for acceptance purposes: alloy steel gear wheel and rim forgings – Normalised and tempered

Tensile strength N/mm^2	Yield stress N/mm^2 minimum	Elongation on $5,65\sqrt{S_o}$ % minimum		Hardness Brinell
		Rims	Wheels	
600–750	330	18	16	175–215
650–800	355	17	15	190–235
700–850	380	16	14	205–245
750–900	405	15	13	215–260
800–950	430	14	12	235–275
850–1000	455	13	11	245–290
Intermediate values may be obtained by interpolation.				

Table 5.5.3 Mechanical properties for acceptance purposes: alloy steel gear forgings – Quenched and tempered

Tensile strength N/mm^2 (*see* Notes 1 and 2)	Yield stress N/mm^2 minimum (*see* Note 2)	Elongation on $5,65\sqrt{S_o}$ % minimum			Hardness Brinell
		A	B	C	
600–750	420	18	16	14	175–215
650–800	450	17	15	13	190–235
700–850	480	16	14	12	205–245
750–900	530	15	13	11	215–260
800–950	590	14	12	10	235–275
850–1000	640	13	11	9	245–290
900–1050	690	13	11	9	260–310
950–1100	750	12	10	8	275–330
1000–1150	810	12	10	8	290–340
1050–1200	870	11	9	7	310–365
Column A is applicable to tests from gear rims and to longitudinal tests from pinions. Column B is applicable to tests from gear wheels and to tangential tests from pinions. Column C is applicable to tests from pinion sleeves.					
Intermediate values may be obtained by interpolation.					
NOTES 1. For gear wheel and rim forgings the specified minimum tensile strength is not to exceed 850 N/mm^2. 2. For carburised gear forgings the requirements for minimum yield stress and maximum tensile strength are not applicable.					

5.5.6 Where more than one tensile test is taken from a forging, the variation in tensile strength is not to exceed the following:

Specified minimum tensile strength N/mm^2	Difference in tensile strength N/mm^2
<600	70
≥600 <900	100
≥900	120

5.5.7 Hardness tests are to be carried out on all forgings after completion of heat treatment and prior to machining the gear teeth. The hardness is to be determined at four positions equally spaced around the circumference of the surface where teeth will subsequently be cut. Where the finished diameter of the toothed portion exceeds 2500 mm, the number of test positions is to be increased to eight. Where the width of a gear wheel rim forging exceeds 1250 mm, the hardness is to be determined at eight positions at each end of the forging.

5.5.8 For small gear forgings which are batch tested, at least one hardness test is to be carried out on each forging.

5.5.9 The results of all hardness tests are to comply with the appropriate requirements of Tables 5.5.1 to 5.5.3. The difference between the highest and lowest values on any one forging is not to exceed the following:

Specified minimum tensile strength (N/mm^2)	Difference in hardness (Brinell number)
<600	25
≥600 <900	35
≥900	42

5.5.10 On nitrided or induction hardened components, hardness tests are also to be made on the teeth when surface hardening and grinding have been completed. The results are to comply with the approved specification.

5.6 Mechanical tests for carburised forgings

5.6.1 Sufficient test material is to be provided for preliminary tests at the forge and for final tests after completion of carburising. For this purpose, duplicate sets of test material are to be taken from positions as detailed in 5.5.1, except that, irrespective of the dimensions or mass of the forging, tests are required from one position only, and in the case of forgings with integral journals are to be cut in a longitudinal direction. The test material which is to be used for measurements of case depth, hardness, grain size and residual austenite as well as mechanical properties is to be machined to a coupon of diameter of $\frac{D}{4}$ or 30 mm, whichever is less, where D is the finished diameter of the toothed portion.

5.6.2 For small forgings, where a system of batch testing is adopted, the test material may be prepared from surplus steel from the same cast provided that the forging reduction approximates to that of the actual gear forgings. The test samples are to be correctly identified and heat treated with the forgings they represent.

5.6.3 For preliminary tests at the forge, one set of test material is to be given a blank carburising and heat treatment cycle simulating that which will be subsequently applied to the forgings.

5.6.4 For final acceptance tests, the second set of test material is to be blank carburised and heat treated together with the forgings which it represents.

5.6.5 At the discretion of the forgemaster or gear manufacturer, test samples of larger cross-section than in 5.6.1 may be either carburised or blank carburised, but these are to be machined to the required diameter prior to the final quenching and stress relieving heat treatment.

5.6.6 At least one tensile specimen is to be prepared from each sample of test material.

5.6.7 Unless otherwise agreed, the specified minimum tensile strength is to be not less than 750 N/mm^2, and the results of all tensile tests are to comply with the requirements given in Table 5.5.3.

5.6.8 Where it is proposed to adopt alternatives to the requirements of 5.6.1 to 5.6.7, full details are to be submitted to the Surveyor for consideration.

5.7 Non-destructive examination

5.7.1 Magnetic particle or liquid penetrant testing is to be carried out on the teeth of all surface hardened forgings. This examination may also be requested on the finished machined teeth of through hardened gear forgings.

5.7.2 The manufacturer is to carry out an ultrasonic examination of all forgings where the finished diameter of the surfaces, where teeth will be cut, is in excess of 200 mm, and is to provide the Surveyor with a signed statement that such inspection has not revealed any significant internal defects.

5.7.3 On gear forgings where the teeth have been surface hardened, additional test pieces may be required to be processed with the forgings and subsequently sectioned to determine the depth of the hardened zone. These tests are to be carried out at the discretion of the Surveyor, and for induction or carburised gearing the depth of the hardened zone is to be in accordance with the approved specification. For nitrided gearing, the full depth of the hardened zone, (i.e., depth to core hardness), is to be not less than 0,5 mm and the hardness at a depth of 0,25 mm is to be not less than 500 HV.

■ *Section 6*
Forgings for turbines

6.1 Scope

6.1.1 Provision is made in this Section for ferritic steel forgings for turbine rotors, discs and spindles, turbine-driven generator rotors and compressor rotors.

6.1.2 Plans for rotor forgings are to state whether the rotor is intended for propulsion or auxiliary machinery and the shaft power of auxiliary turbines. In the case of a rotor which is to be tested for thermal stability, the maximum operating temperature and the proposed test temperature are also to be stated.

6.1.3 Specifications of alloy steel forgings giving the proposed chemical composition, heat treatment and mechanical properties are to be submitted for approval with the plans of the components.

6.1.4 Where it is proposed to use rotors of welded construction, the compositions of the steels for the forgings are to be submitted for special consideration, together with details of the proposed welding procedure. Welding procedure tests may be required.

6.2 Manufacture

6.2.1 Forgings are to be manufactured in accordance with the requirements of Section 1, except that for rotors the forging reduction is to be not less than 2,5 to 1. Where an upsetting operation is included in the manufacturing procedure, the above requirement applies to the cross-sectional area of the upset bloom and not to that of the ingot.

6.3 Chemical composition

6.3.1 The chemical composition of ladle samples is to comply with 3.2.1 for carbon and carbon-manganese steels and 1.4.3 for alloy steels.

6.4 Heat treatment

6.4.1 Forgings are to be supplied in the heat treated condition, and the thermal treatment at all stages is to be such as to avoid the formation of hair-line cracks. At a suitable stage of manufacture, the forgings are to be reheated above the upper critical point to refine the grain, cooled in an approved manner and then tempered to produce the desired mechanical properties.

6.4.2 Where forgings receive their main heat treatment before machining, they are to be stress relieved after rough machining. Forgings which are heat treated in the rough machined condition need not be stress relieved provided that they have been slowly cooled from the tempering temperature.

6.4.3 The tempering and stress relieving temperatures are to be not less than 550°C for carbon and carbon-manganese steels, and not less than 600°C for alloy steels. The holding times and subsequent cooling rates are to be such that the forging in its final condition is free from harmful residual stresses.

6.4.4 Details of the proposed heat treatment for rotors of welded construction are to be submitted for approval.

6.5 Mechanical tests

6.5.1 At least one tensile test specimen, cut in a longitudinal direction, is to be taken from each rotor forging. For forgings exceeding both 3 tonnes in mass and 2000 mm in length, tests are to be taken from each end.

6.5.2 For rotor forgings of all main propulsion machinery and of auxiliary turbines exceeding 1100 kW, tangential and, where the dimensions permit, radial tensile tests are to be taken from the end of the body corresponding to the top end of the ingot, *see* Fig. 5.6.1.

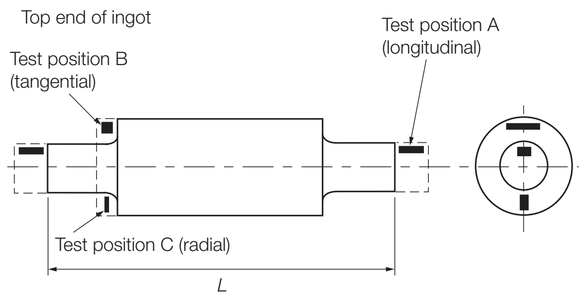


Fig. 5.6.1 Test positions for turbine rotor forgings

6.5.3 For each turbine disc, at least one tensile test specimen is to be cut in a tangential direction from material at the hub, *see* Fig. 5.6.2.

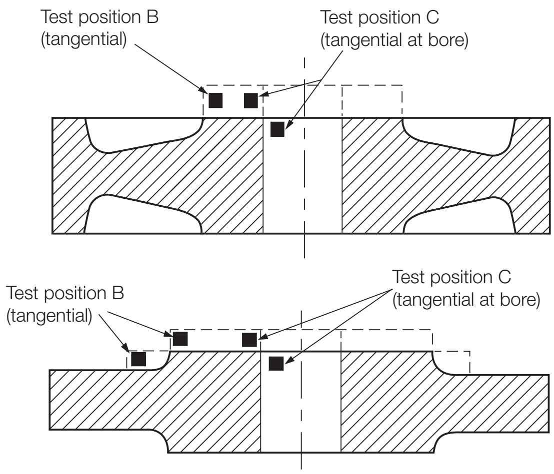


Fig. 5.6.2 Test positions for turbine disc forgings

6.5.4 For the tests required by 6.5.1 to 6.5.3, sufficient test material is to be left on each forging and is not to be removed until all heat treatment, including stress relieving, has been completed. In this connection, a thermal stability test does not form part of the heat treatment of a turbine forging. Any excess test material is not to be completely severed from a forging until all the mechanical tests have been completed with satisfactory results.

6.5.5 Tables 5.6.1 and 5.6.2 give the minimum requirements for yield stress, elongation and reduction of area corresponding to different strength levels, but it is not intended that these should necessarily be regarded as specific grades. The strength levels have been given in multiples of 40 N/mm^2, or 50 N/mm^2 for alloy steels, to facilitate interpolation for intermediate values of specified minimum tensile strength.

Table 5.6.1 Mechanical properties for acceptance purposes: carbon-manganese steel forgings for turbines – Normalised and tempered

Tensile strength N/mm^2	Yield stress N/mm^2 minimum	Elongation $5,65\sqrt{S_o}$ % minimum			Reduction of area % minimum		
		A	B	C	A	B	C
400–520	200	26	22	18	50	40	35
440–560	220	24	21	17	50	40	35
480–600	240	22	19	15	45	35	30
520–640	260	21	18	14	45	35	30
560–680	280	20	17	13	40	30	25
600–720	300	18	15	12	40	30	25

NOTES
Columns A are applicable to longitudinal tests from rotor and spindle forgings.
Columns B are applicable to tangential tests from rotor forgings.
Columns C are applicable to radial tests from rotor forgings.
Intermediate values may be obtained by interpolation.

6.5.6 Forgings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Table 5.6.1 or Table 5.6.2.

6.5.7 The results of all tensile tests are to comply with the requirements of Table 5.6.1 or Table 5.6.2 appropriate to the specified minimum tensile strength. For monobloc rotor forgings, the specified minimum tensile strength is not to exceed 800 N/mm^2.

6.6 Non-destructive examination

6.6.1 The end faces of the body of rotor forgings and the end faces of the boss and the bore surface of each turbine disc are to be machined to a fine smooth finish for visual and magnetic particle examination.

6.6.2 The manufacturer is to carry out an ultrasonic examination of each forging and is to provide the Surveyor with a signed statement that such inspection has not revealed any significant internal defects.

6.6.3 Rotor forgings for propulsion machinery and for auxiliary turbines exceeding 1100 kW are to be hollow bored for internal examination. The surface of the bore is to have a fine smooth finish and is to be examined by means of an optical instrument of suitable magnification. Where the bore size permits, magnetic particle examination is also to be carried out. These examinations are to be confirmed by the Surveyor. Alternatively, an approved method of ultrasonic examination may be accepted instead of hollow boring. Details of the proposed method of ultrasonic examination are to be submitted for special consideration.

Table 5.6.2 Mechanical properties for acceptance purposes: alloy steel forgings for turbines – Quenched and tempered or normalised and tempered

Tensile strength N/mm^2 (*see* Note)	Yield stress N/mm^2 minimum Normalised and tempered	Yield stress N/mm^2 minimum Quenched and tempered	Elongation on $5,65\sqrt{S_o}$ % minimum			Reduction of area %minimum		
			A	B	C	A	B	C
500 – 650	275	—	22	20	18	50	40	35
550 – 700	300	—	20	18	16	50	40	35
600 – 750	330	410	18	16	14	50	40	35
650 – 800	355	450	17	15	13	50	40	35
700 – 850	385	490	16	14	12	45	35	30
750 – 900	—	530	15	13	11	45	35	30
800 – 950	—	590	14	12	10	45	35	30
850 – 1000	—	640	13	11	9	40	30	25
900 – 1050	—	690	13	11	9	40	30	25
950 – 1100	—	750	12	10	8	40	30	25
1000 – 1150	—	810	12	10	8	40	30	25

NOTES
Columns A are applicable to longitudinal tests from rotor and spindle forgings.
Columns B are applicable to tangential tests from rotor and spindle forgings, and to tangential tests from discs – test position B in Fig. 5.6.2.
Columns C are applicable to radial test from rotor forgings and to tangential tests from discs – test position C in Fig. 5.6.2.
Intermediate values may be obtained by interpolation.

6.7 Thermal stability tests

6.7.1 Thermal stability tests after heat treatment and rough machining of the turbine rotors, referred to in the relevant Rules dealing with design and construction, are to be undertaken in properly constructed furnaces, using accurate and reliable measuring equipment. Each test is to be carried out in accordance with the following recommended procedure:

(a) Five bands are to be machined concentric with the axis of rotation. Two of these are to be reference bands and are to be positioned at or near the locations of the bearings. The remaining three bands are to be test bands located one as near as possible to the mid-length, and the other two near each end of the body. Where the length of a rotor is such that five bands cannot be provided, alternative proposals are to be submitted to the Surveyor for his approval.

(b) Four positions, 90° apart, are to be stamped A, B, C and D on the coupling end of the rotor.

(c) The whole of the body, and as much of the shaft at either end as will include the positions of the glands, is to be enclosed in the furnace. In the case of a rotor having an overhung astern wheel, the astern wheel is also to be enclosed in the furnace during the first test.

(d) The rotor is to be rotated at a uniform and very low speed.

(e) The deflections at all bands are to be recorded at the A, B, C and D positions. Initial cold readings are to be taken prior to heating.

(f) The rotor is to be heated uniformly and slowly. Temperatures are to be recorded continuously at the surface of the rotor and, if practicable, in the bore at the mid-length of the body. In no circumstances is the surface temperature to exceed the temperature at which the rotor was tempered. During heating, the rate of rise of temperature is to be such as to avoid excessive temperature gradients in the rotor.

(g) The maximum or holding temperature is to be not less than 28°C above the maximum operating temperature of the rotor. For the purposes of the test, the holding period is to start when the rotor has attained a uniform and specified temperature. The rotor is to be held under the specified temperature conditions until not less than three consecutive hourly readings of deflections show the radial eccentricity to be constant within 0,006 mm on all test bands.

(h) The turbine rotor is to be rotated during cooling until the temperature is not more than 100°C. The rate of cooling is to be such as to avoid excessive temperature gradients in the rotor.

(j) Final cold readings are to be taken.

6.7.2 The movements of the axis of the rotor in relation to the reference bands are to be determined from polar plots of the deflection readings. The radial movement of the shaft axis, as determined by the difference between the final hot and the final cold movements, is not to exceed 0,025 mm on any one band. As verification that test equipment and conditions are satisfactory, it is required that similar determinations of differences between initial cold and final cold movements do not exceed 0,025 mm on any one band.

6.7.3 If the results of the test on a rotor fail to meet either or both of the requirements in 6.7.2, the test may be repeated if requested by the maker and agreed by the Surveyor. In the case of a rotor failing to meet the requirements of a thermal stability test, the rotor is deemed unacceptable. Proposals for the rectification of thermal instability of a rough machined rotor are to be submitted for special consideration.

■ *Section 7*
Forgings for boilers, pressure vessels and piping systems

7.1 Scope

7.1.1 Provision is made in this Section for carbon-manganese and low alloy steel forgings intended for use in the construction of boilers, pressure vessels and piping systems where the design temperature is not lower than 0°C.

7.1.2 In addition to specifying mechanical properties at ambient temperature for the purposes of acceptance testing, these requirements give details of appropriate mechanical properties at elevated temperatures to be used for design purposes.

7.1.3 Forgings used in the construction of equipment for the containment of liquefied gases are to comply with the requirements of Section 8, except for those used in piping systems, where the design temperature is not lower than 0°C. Forgings for other pressure vessels and piping systems, where the use of steels with guaranteed impact properties at low temperatures is required, are also to comply with Section 8.

7.2 Chemical composition

7.2.1 The chemical composition of ladle samples is to comply with the appropriate requirements of Table 5.7.1.

7.3 Heat treatment

7.3.1 Carbon-manganese steel forgings are to be normalised, normalised and tempered or quenched and tempered.

7.3.2 Alloy steel forgings are to be normalised and tempered or quenched and tempered.

7.3.3 No forging is to be fully heat treated more than twice.

7.4 Mechanical tests

7.4.1 Except as provided in 7.4.2 and 7.4.4, at least one tensile test is to be taken from each forging and, where the dimensions and shape allow, the test specimen is to be cut in the longitudinal direction.

Table 5.7.1 Chemical composition

Type of steel	Tensile strength N/mm^2	Chemical composition of ladle samples %							
		C max.	Si	Mn	P max.	S max.	Al	Residual elements	
Carbon-manganese	410–530	0,20	0,10–0,40	0,50–1,20	0,030	0,025	(*See* Notes 1 and 3)	Ni 0,40 max. Cr 0,25 max. Mo 0,10 max. Cu 0,30 max. Total 0,80 max.	
	460–580	0,23		0,80–1,40					
	490–610	0,25		0,90–1,70					
								Cr	Mo
Alloy steel 1Cr$^1/_2$Mo	440–590	0,18	0,15–0,40	0,40–0,70	0,030	0,025	0,020 max. (*See* Note 2)	0,85–1,15	0,45–0,65
Alloy steel 2$^1/_4$ Cr1Mo	490–640	0,15						2,0–2,5	0,90–1,20

NOTES
1. Fine grained steels are to contain:
   aluminium (acid soluble) 0,015% min. or
   aluminium (total) 0,018% min.
2. For alloy steels, aluminium (acid soluble) 0,020% max.
   The determination of the aluminium (total) content is acceptable provided the above value is not exceeded.
3. Niobium may be used as a grain refiner in place of aluminium, in which case the content is to be in the range 0,01% to 0,06%.

7.4.2 On seamless drums and headers which are initially forged with open ends, test material is to be provided at each end of each forging. Where forged with one solid end, test material is to be provided at the open end only. Except where the ends are to be subsequently closed by forging, the test material is not to be removed until heat treatment has been completed. Where the ends are to be closed, rings of test material are to be cut off prior to the closing operation and are to be heat treated with the finished forging. In all cases, the test specimens are to be cut in the circumferential direction.

7.4.3 Unless otherwise agreed, tensile test specimens are to be taken with their axis at approximately 12,5 mm below the surface of the forging.

7.4.4 Small forgings may be batch tested in accordance with 1.6.4 provided that hardness tests are carried out on each forging. In such cases, the mass of each forging is not to exceed 1 tonne and that of the batch is not to exceed 10 tonnes and the hardness values are to accord with Table 5.7.2.

Table 5.7.2 Mechanical properties for acceptance purposes

Type of steel	Diameter or equivalent thickness mm	Yield stress N/mm^2	Tensile strength N/mm^2	Elongation on $5,65\sqrt{S_o}$ % minimum	Hardness Brinell
Carbon-manganese not specifically fine grained	≤100	215	410–530	20	110–155
	>100 ≤500	205			
	≤100	245	460–580	18	130–170
	>100	235			
	≤100	265	490–610	16	140–180
	>100	255			
Carbon-manganese, fine grained	≤100	235	410–530	20	110–155
	>100 ≤250	220			
	≤100	275	460–580	18	130–170
	>100 ≤250	255			
	≤100	305	490–610	16	140–180
	>100 ≤250	280			
Alloy steel 1Cr$^1/_2$Mo	–	275	440–590	19	110–160
2$^1/_4$Cr1Mo	–	275	490–640	18	140–185

7.4.5 If required by the Surveyors or by the Fabricators, test material may be given a simulated stress relieving heat treatment prior to the preparation of the test specimens. This has to be stated on the order, together with agreed details of the simulated heat treatment and the mechanical properties which can be expected.

7.4.6 Except as provided in 7.4.7, the results of all tensile tests are to comply with the requirements given in Table 5.7.2 appropriate to the specified minimum tensile strength.

7.4.7 Where tests are taken at a depth greater than 12,5 mm from the surface or where they are taken in a transverse direction, the mechanical properties which can be expected are to be agreed.

7.4.8 On seamless drums and headers where tests are taken from each end, the variation in tensile strength is not to exceed 70 N/mm^2.

7.4.9 For small batch-tested forgings, the hardness values are to comply with the requirements of Table 5.7.2 appropriate to the specified minimum tensile strength. If forgings of more than one thickness are to be supplied from one cast, then the test is to be made on the thickest forging.

7.5 Non-destructive examination

7.5.1 Non-destructive testing is to be carried out in accordance with the requirements of the approved forging drawing and specification, or as otherwise agreed between the manufacturer, purchaser and Surveyor.

7.6 Pressure tests

7.6.1 Where applicable, pressure tests are to be carried out in accordance with the requirements of the relevant Rules.

7.7 Mechanical properties for design purposes

7.7.1 Nominal values for the minimum lower yield or 0,2 per cent proof stress at temperatures of 50°C and higher are given in Table 5.7.3. These values are intended for design purposes only, and verification is not required except for materials complying with National or proprietary specifications where the elevated temperature properties used for design purposes are higher than those given in Table 5.7.3.

Table 5.7.3 Mechanical properties for design purposes

Type of steel	Diameter or equivalent thickness mm	Tensile strength N/mm^2	Nominal minimum lower yield or 0,2% proof stress N/mm^2											
			Temperature °C											
			50	100	150	200	250	300	350	400	450	500	550	600
Carbon-manganese not specifically fine grained	≤100	410–530	196	192	188	181	168	150	142	138	136	—	–	—
	>100		183	178	175	170	162	150	142	138	136	—	—	—
	≤100	460–580	227	222	218	210	194	176	168	162	158	—	—	—
	>100		212	206	203	197	188	176	168	162	158	—	—	—
	≤100	490–610	245	240	236	227	210	192	183	177	172	—	—	—
	>100		229	222	219	212	203	192	183	177	172	—	—	—
Carbon-manganese fine grained	≤100	410–530	222	215	204	188	171	152	141	134	130	—	—	—
	>100		207	200	190	175	164	152	141	134	130	—	—	—
	≤100	460–580	262	251	236	217	198	177	167	158	153	—	—	—
	>100		244	233	220	202	190	177	167	158	153	—	—	—
	≤100	490–610	286	272	256	234	213	192	182	173	168	—	—	—
	>100		266	253	238	218	205	192	182	173	168	—	—	—
Alloy steel 1Cr$^1/_2$Mo	—	410–560	254	241	224	213	197	184	170	162	157	151	146	145
2$^1/_4$ Cr1Mo	—	490–640	268	261	253	245	236	230	224	218	205	189	167	145

7.7.2 Where verification is required, at least one tensile test at the proposed design or other agreed temperature is to be made on each forging or each batch of forgings. The test specimen is to be taken from material adjacent to that used for tests at ambient temperature, and the test procedure is to be in accordance with the requirements of Chapter 2. The results of all tests are to comply with the requirements of the National or proprietary specification.

7.7.3 Values for the estimated average stress to rupture in 100 000 hours are given in Table 5.7.4 and may be used for design purposes.

Table 5.7.4 Mechanical properties for design purposes: estimated average values for stress to rupture in 100 000 hours (units N/mm^2)

Temperature °C	Grades of steel		
	Carbon-manganese	1 Cr $^1/_2$ Mo	$2^1/_4$ Cr 1Mo
380	227	–	–
390	203	–	–
400	179	–	–
410	157	–	–
420	136	–	–
430	117	–	–
440	100	–	–
450	85	290	–
460	73	262	–
470	63	235	210
480	55	208	186
490	–	181	165
500	–	155	145
510	–	129	128
520	–	103	112
530	–	80	98
540	–	62	84
550	–	49	72
560	–	42	61
570	–	36	49
580	–	32	–
590	–	29	–

■ *Section 8*
Ferritic steel forgings for low temperature service

8.1 Scope

8.1.1 The requirements for carbon-manganese and nickel steels suitable for low temperature service are detailed in this Section. They are applicable to all forgings used for the construction of cargo tanks, storage tanks and process pressure vessels for liquefied gases and, where the design temperature is less than 0°C, to forgings for the piping systems.

8.1.2 The requirements are also applicable to forgings for other pressure vessels and pressure piping systems where the use of steels with guaranteed impact properties at low temperatures is required.

8.1.3 In all cases, details of the proposed chemical composition, heat treatment and mechanical properties are to be submitted for approval.

8.1.4 In addition to the steels in this Section, the austenitic stainless steels detailed in Section 9 may also be used for low temperature applications.

8.2 Chemical composition

8.2.1 The chemical composition of ladle samples is, in general, to comply with the requirements given in Table 5.8.1.

8.3 Heat treatment

8.3.1 Forgings are to be normalised, normalised and tempered or quenched and tempered in accordance with the approved specification.

8.4 Mechanical tests

8.4.1 At least one tensile and three Charpy V-notch impact test specimens are to be taken from each forging or each batch of forgings. Where the dimensions and shape allow, the test specimens are to be cut in a longitudinal direction.

8.4.2 The impact tests are to be carried out at a temperature appropriate to the type of steel and for the proposed application. Where forgings are intended for ships for liquefied gases, the test temperature is to be in accordance with the requirements given in Table 3.6.3 in Chapter 3.

8.4.3 The results of all tensile tests are to comply with the approved specification.

8.4.4 The average energy values for impact tests are also to comply with the approved specification and generally with the requirements of Ch 3,6. One individual value may be less than the required average value provided that it is not less than 70 per cent of this value. *See* Ch 2,1.4 for re-test procedures.

Table 5.8.1 Chemical composition of ferritic steel forgings

<table>
<tr><th rowspan="2">Grade of steel</th><th rowspan="2">C
%</th><th rowspan="2">Si
%</th><th rowspan="2">Mn
%</th><th rowspan="2">Ni
%</th><th rowspan="2">P
%</th><th rowspan="2">S
%</th><th rowspan="2">Residual
elements %</th><th colspan="2">Grain refiners %</th></tr>
<tr><th>Al</th><th>Other</th></tr>
<tr><td>LT–AH (AH40)
LT–DH (DH40)
LT–EH (EH40)</td><td>0,18
max.</td><td rowspan="2">0,50
max.</td><td rowspan="2">0,90–1,60</td><td>0,40
max.</td><td>0,035
max.</td><td>0,030
max.</td><td rowspan="2">Cu 0,35 max.
Cr 0,20 max.
Mo 0,08 max.

Total 0,60 max.</td><td rowspan="6">Total
0,020 min.

Acid soluble
0,015 min.</td><td rowspan="2">(*See* Note)

Nb 0,02 – 0,05
V 0,03 – 0,10
Ti 0,02 max.</td></tr>
<tr><td>LT–FH (FH40)</td><td>0,16
max.</td><td>0,80
max.</td><td rowspan="5">0,025
max.</td><td>0,025
max.</td></tr>
<tr><td>1 1/2Ni</td><td>0,18
max.</td><td rowspan="4">0,10 – 0,35</td><td>0,30–1,50</td><td>1,30–1,70</td><td rowspan="4">0,020
max.</td><td rowspan="4">Cu 0,35 max.
Cr 0,25 max.
Mo 0,08 max.

Total 0,60 max.</td><td rowspan="4"></td></tr>
<tr><td>3 1/2Ni</td><td>0,15
max.</td><td rowspan="3">0,30–0,90</td><td>3,20–3,80</td></tr>
<tr><td>5Ni</td><td>0,12
max.</td><td>4,70–5,30</td></tr>
<tr><td>9 Ni</td><td>0,10
max.</td><td>8,50–10,0</td></tr>
<tr><td colspan="10">NOTE
The steel is to contain aluminium, niobium, vanadium or other suitable grain refining elements, either singly or in any combination. When used singly, the steel is to contain the specified minimum content of the grain refining element. When used in combination, the specified minimum content of each element is not applicable.</td></tr>
</table>

8.5 Non-destructive examination

8.5.1 Non-destructive testing is to be carried out in accordance with the requirements of the approved forging drawing and specification, or as otherwise agreed between the manufacturer, purchaser and Surveyor.

8.6 Pressure tests

8.6.1 When applicable, pressure tests are to be carried out in accordance with the requirements of the relevant Rules.

■ *Section 9* Austenitic stainless steel forgings

9.1 General

9.1.1 Forgings in austenitic stainless steels are acceptable for use in the construction of cargo tanks, storage tanks and piping systems for chemicals and liquefied gases. They may also be accepted for elevated temperature service in boilers.

9.1.2 Where it is proposed to use forgings in these types of steels, details of the chemical composition, heat treatment and mechanical properties are to be submitted for approval. These are to comply, in general, with the requirements of Ch 3,7 for austenitic steel plates.

9.1.3 Unless otherwise agreed, impact tests are not required for acceptance purposes. Where they are required, tests are to be made on longitudinal specimens at minus 196°C and the minimum average energy requirement is to be 41J.

9.2 Mechanical properties for design purposes

9.2.1 Where austenitic stainless steel forgings are intended for service at elevated temperatures, the nominal values for the minimum one per cent proof stress at temperatures of 100°C and higher given in Table 5.9.1 may be used for design purposes. Verification of these values is not required except for material complying with a National or proprietary specification in which the elevated temperature properties proposed for design purposes are higher than those given in Table 5.9.1.

9.3 Non-destructive examination

9.3.1 Non-destructive examination is to be carried out in accordance with the requirements of the approved forging drawing and specification or as otherwise agreed between the manufacturer, purchaser and Surveyor.

9.4 Intergranular corrosion tests

9.4.1 Where corrosive conditions are anticipated in service, intergranular corrosion tests are required on forgings in Grades 304, 316 and 317. Such tests may not be required for Grades 304L, 316L, 321 and 347.

Table 5.9.1 Mechanical properties for design purposes: austenitic stainless steels

Grade	Nominal 1% proof stress (N/mm^2) at a temperature of												
	100°C	150°C	200°C	250°C	300°C	350°C	400°C	450°C	500°C	550°C	600°C	650°C	700°C
304L	168	150	137	128	122	116	110	108	106	102	100	96	93
316L	177	161	149	139	133	127	123	119	115	112	110	107	105
316LN	238	208	192	180	172	166	161	157	152	149	144	142	138
321	192	180	172	164	158	152	148	144	140	138	135	130	124
347	204	192	182	172	166	162	159	157	155	153	151	—	—

9.4.2 When an intergranular corrosion test is specified, it is to be carried out in accordance with the procedure given in Ch 2,9.1.

Section

■ *Section 1* General requirements

1.1 Scope

1.1.1 This Section gives the general requirements for boiler tubes, superheater tubes and pipes intended for use in the construction of boilers, pressure vessels and pressure piping systems.

1.1.2 In addition to specifying mechanical properties for the purpose of acceptance testing, these requirements give details of appropriate mechanical properties at elevated temperatures to be used for design purposes.

1.1.3 Except for pipes for Class III pressure systems (as defined in the relevant Rules), all pipes and tubes are to be manufactured and tested in accordance with the requirements of Chapters 1 and 2, the general requirements of this Section and the appropriate specific requirements given in Sections 2, 3, 4, 5 and 6.

1.1.4 Steels intended for the piping systems for liquefied gases where the design temperature is less than 0°C are to comply with the specific requirements of Section 4 or 5.

1.1.5 As an alternative to 1.1.3 and 1.1.4, pipes or tubes which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Chapter or alternatively are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

1.1.6 At the discretion of the Surveyor, a modified testing procedure may be adopted for small quantities of materials. In such cases, these may be accepted on the manufacturer's declared chemical composition and hardness tests or other evidence of satisfactory properties.

1.1.7 Pipes for Class III pressure systems are to be manufactured and tested in accordance with the requirements of an acceptable National specification. The manufacturer's test certificate will be acceptable and is to be provided for each consignment of material. Forge butt welded pipes are not acceptable for oil fuel systems, heating coils in oil tanks, primary refrigerant systems and other applications where the pressure exceeds 4,0 bar (4,1 kgf/cm^2).

1.2 Manufacture

1.2.1 Pipes for Class I and II pressure systems, boiler and superheater tubes are to be manufactured at works approved by Lloyd's Register (hereinafter referred to as 'LR'). The steel used is to be manufactured and cast in ingot moulds or by an approved continuous casting process as detailed in Ch 3,1.4.

1.2.2 Unless a particular method is requested by the purchaser, pipes and tubes may be manufactured by any of the following methods:
- Hot finished seamless.
- Cold finished seamless.
- Electric resistance or induction welded.
- Cold finished electric resistance or induction welded.
- Electric fusion welded.

1.2.3 Care is to be taken during manufacture that the pipe or tube surfaces coming in contact with any non-ferrous metals or their compounds are not contaminated to such an extent as could prove harmful during subsequent fabrication and operation.

1.3 Quality

1.3.1 All pipes and tubes are to have a workmanlike finish and are to be clean and free from such surface and internal defects as can be established by the specified tests.

1.3.2 All pipes and tubes are to be reasonably straight. The ends are to be cut nominally square with the axis of the pipe or tube, and are to be free from excessive burrs.

1.4 Dimensional tolerances

1.4.1 The tolerances on the wall thickness and diameter of pipes and tubes are to be in accordance with an acceptable National specification.

1.5 Chemical composition

1.5.1 The requirements for the chemical composition of ladle samples and acceptable methods of deoxidation are detailed in subsequent Sections in this Chapter.

1.6 Heat treatment

1.6.1 All pipes and tubes are to be supplied in the condition detailed in the relevant specific requirements.

1.7 Test material

1.7.1 Pipes and tubes are to be presented for test in batches. The size of a batch and the number of tests to be performed are dependent on the application.

1.7.2 Where heat treatment has been carried out, a batch is to consist of pipes or tubes of the same size, manufactured from the same types of steel and subjected to the same finishing treatment in a continuous furnace, or heat treated together in the same batch type furnace.

1.7.3 Where no heat treatment has been carried out, a batch is to consist of pipes or tubes of the same size manufactured by the same method from material of the same type of steel.

1.7.4 For pipes for Class I pressure systems and boiler and superheater tubes, at least two per cent of the number of lengths in each batch is to be selected at random for the preparation of tests at ambient temperature.

1.7.5 For pipes for Class II pressure systems, each batch is to contain not more than the number of lengths given in Table 6.1.1. Tests are to be carried out on at least one pipe selected at random from each batch or part thereof.

Table 6.1.1 Batch sizes for pipes for Class II pressure systems

Outside diameter mm	Number in batch
≤323,9	200 pipes as made
>323,9	100 pipes as made

1.8 Dimensions of test specimens and test procedures

1.8.1 The procedures for mechanical tests and the dimensions of the test specimens are to be in accordance with Chapter 2.

1.9 Visual and non-destructive testing

1.9.1 All pipes for Class I and II pressure systems, boiler and superheater tubes, are to be presented for visual examination and verification of dimensions. The manufacturer is to provide adequate lighting conditions to enable an internal and external examination of the pipes and tubes to be carried out.

1.9.2 For welded pipes and tubes, the manufacturer is to employ suitable non-destructive methods for the quality control of the welds. It is preferred that this examination is carried out on a continuous basis.

1.10 Hydraulic test

1.10.1 Each pipe and tube is to be subjected to a hydraulic test at the manufacturer's works.

1.10.2 The hydraulic test pressure is to be determined from the following formula, except that the maximum test pressure need not exceed 140 bar (143 kgf/cm^2):

$$P = \frac{20st}{D} \left(P = \frac{200st}{D}\right)$$

where

P = test pressure, in bar (kgf/cm^2)
D = nominal outside diameter, in mm
t = nominal wall thickness, in mm
s = 80 per cent of the specified minimum yield stress, in N/mm^2 (kgf/mm^2), for ferritic steels and 70 per cent of the specified minimum, 1,0 per cent proof stress, in N/mm^2 (kgf/mm^2), for austenitic steels. These relate to the values specified for acceptance testing at ambient temperature.

1.10.3 The test pressure is to be maintained for sufficient time to permit proof and inspection. Unless otherwise agreed, the manufacturer's certificate of satisfactory hydraulic test will be accepted. Where it is proposed to adopt a test pressure other than that determined as in 1.10.2, the proposal will be subject to special consideration.

1.10.4 Subject to special approval, either an ultrasonic or eddy current test can be accepted in lieu of the hydraulic test.

1.11 Rectification of defects

1.11.1 Surface imperfections may be removed by grinding provided that the thickness of the pipe or tube after dressing is not less than the required minimum thickness. The dressed area is to be blended into the contour of the tube.

1.11.2 By agreement with the Surveyor, the repair of minor defects by welding can be accepted, subject to welding procedure tests which demonstrate acceptable properties appropriate for the grade of pipe to be repaired. Weld procedure tests are to be subjected to the same heat treatment as will be applied to the actual pipes after weld repair.

1.11.3 The repaired area is to be tested by magnetic particle examination, or, for austenitic steels, by liquid penetrant examination on completion of welding, heat treatment and surface grinding.

1.12 Identification

1.12.1 Pipes and tubes are to be clearly marked by the manufacturer in accordance with the requirements of Chapter 1. The following details are to be shown on all materials which have been accepted:

(a) LR or Lloyd's Register.
(b) Manufacturer's name or trade mark.
(c) Identification mark for the specification or grade of steel.
(d) Identification number and/or initials which will enable the full history of the item to be traced.
(e) The personal stamp of the Surveyor responsible for the final inspection.

1.12.2 It is recommended that hard stamping be restricted to the end face, but it may be accepted in other positions in accordance with National Standards and practices.

1.13 Certification of materials

1.13.1 Unless a LR certificate is specified in other parts of the Rules, a manufacturer's certificate validated by LR is to be issued, *see* Ch 1,3.1.

1.13.2 The manufacturer is to provide LR with the following information:

(a) Purchaser's name and order number.
(b) If known, the contract number for which the material is intended.
(c) Address to which material is despatched.
(d) Specification or the grade of material.
(e) Description and dimensions.
(f) Identification number and/or initials.
(g) Cast number and chemical composition of ladle samples.
(h) Mechanical test results, and results of the intercrystalline corrosion tests where applicable.
(j) Condition of supply.

1.13.3 As a minimum, the chemical composition stated on the certificate is to include the content of all the elements detailed in the specific requirements. Where rimming steel is supplied, this is to be stated on the certificate.

1.13.4 When steel is not produced at the pipe or tube mill, a certificate is to be supplied by the steelmaker stating the process of manufacture, the cast number and the ladle analysis.

1.13.5 The steel manufacturer's works is to be approved by LR.

■ *Section 2* Seamless pressure pipes

2.1 Scope

2.1.1 Provision is made in this Section for seamless pressure pipes in carbon, carbon-manganese and low alloy steels.

2.1.2 Where pipes are used for the manufacture of pressure vessel shells and headers, the requirements for forgings in Ch 5,7 are applicable where the wall thickness exceeds 40 mm.

2.2 Manufacture and chemical composition

2.2.1 Pipes are to be manufactured by a seamless process and may be hot or cold finished.

2.2.2 The method of deoxidation and the chemical composition of ladle samples are to comply with the appropriate requirements given in Table 6.2.1.

Table 6.2.1 Chemical composition of seamless pressure pipes

Type of steel	Grade	Method of deoxidation	Chemical composition of ladle samples %											
			C	Si	Mn	S max.	P max.	Residual elements						
Carbon and carbon-manganese	320	Semi-killed or killed	≤0,16	–	0,40–0,70	0,050	0,050	Ni 0,30 max. Cr 0,25 max. Mo 0,10 max. Cu 0,30 max. Total 0,70 max.						
	360		≤0,17	≤0,35	0,40–0,80	0,045	0,045							
	410	Killed	≤0,21	≤0,35	0,40–1,20	0,045	0,045							
	460		≤0,22	≤0,35	0,80–1,40	0,045	0,045							
	490		≤0,23	≤0,35	0,80–1,50	0,045	0,045							
								Ni	Cr	Mo	Cu	Sn	V	Al
1Cr1/2Mo	440	Killed	0,10–0,18	0,10–0,35	0,40–0,70	0,040	0,040	0,30 max.	0,70–1,10	0,45 – 0,65	0,25 max.	0,03 max.	—	≤0,020
2 1/4Cr1Mo	410 490	Killed	0,08–0,15	0,10–0,50	0,40–0,70	0,040	0,040	0,30 max.	2,0–2,5	0,90–1,20	0,25 max.	0,03 max.	—	≤0,020
1/2Cr1/2Mo1/4V	460	Killed	0,10–0,18	0,10–0,35	0,40–0,70	0,040	0,040	0,30	0,30–0,60	0,50–0,70	0,25 max.	0,03 max.	0,22–0,32	≤0,020

2.3 Heat treatment

2.3.1 Pipes are to be supplied in the condition given in Table 6.2.3.

2.4 Mechanical tests

2.4.1 All pipes are to be presented in batches as defined in Section 1.

2.4.2 Each pressure pipe selected for test is to be subjected to tensile and flattening or bend tests.

2.4.3 The results of all mechanical tests are to comply with the appropriate requirements given in Table 6.2.2.

2.5 Mechanical properties for design

2.5.1 Values for nominal minimum lower yield or 0,2 per cent proof stress at temperatures of 50°C and higher are given in Table 6.2.4 and are intended for design purposes only. Verification of these values is not required, except for materials complying with National or proprietary specification where the elevated temperature properties used for design are higher than those given in Table 6.2.4.

2.5.2 In such cases, at least one tensile test at the proposed design or other agreed temperature is to be made on each cast. The test specimen is to be taken from material adjacent to that used for tests at ambient temperature and tested in accordance with the procedures given in Chapter 2. If tubes or pipes of more than one thickness are supplied from one cast, the test is to be made on the thickest tube or pipe.

Table 6.2.3 Heat treatment

Type of steel		Condition of supply
Carbon and carbon-manganese		
Hot finished		Hot finished (*see* Note 1) Normalised (*see* Note 2)
Cold finished		Normalised (*see* Note 2)
Alloy steel		
$1Cr^1/_2Mo$		Normalised and tempered
$2^1/_4Cr1Mo$	Grade 410	Fully annealed
	Grade 490	Normalised and tempered 650—780°C
	Grade 490	Normalised and tempered 650—750°C
$^1/_2Cr^1/_2Mo^1/_4V$		Normalised and tempered

NOTES
1. Provided that the finishing temperature is sufficiently high to soften the material.
2. Normalised and tempered at the option of the manufacturer.

2.5.3 As an alternative to 2.5.2, a manufacturer may carry out an agreed comprehensive test program for a stated grade of steel to demonstrate that the specified minimum mechanical properties at elevated temperatures can be consistently obtained. This test program is to be carried out under the supervision of the Surveyors, and the results submitted for assessment and approval. When a manufacturer is approved on this basis, tensile tests at elevated temperatures are not required for acceptance purposes, but at the discretion of the Surveyors occasional check tests of this type may be requested.

2.5.4 Values for the estimated average stress to rupture in 100 000 hours are given in Table 6.2.5 and may be used for design purposes.

Table 6.2.2 Mechanical properties for acceptance purposes: seamless pressure pipes (maximum wall thickness 40 mm), *see* 2.1.2

Type of steel	Grade	Yield stress N/mm^2	Tensile strength N/mm^2	Elongation on $5,65\sqrt{S_0}$ % minimum	Flattening test constant C	Bend test diameter of former (t = thickness)
Carbon and carbon-manganese	320	195	320—440	25	0,10	$4t$
	360	215	360—480	24	0,10	
	410	235	410—530	22	0,08	
	460	265	460—580	21	0,07	
	490	285	490—610	21	0,07	
$1Cr^1/_2Mo$	440	275	440—590	22	0,07	$4t$
$2^1/_4Cr1Mo$	410 (*see* Note 1)	135	410—560	20	0,07	$4t$
	490 (*see* Note 2)	275	490—640	16		
$^1/_2Cr^1/_2Mo^1/_4V$	460	275	460—610	15	0,07	$4t$

NOTES
1. Annealed condition.
2. Normalised and tempered condition.

Table 6.2.4 Mechanical properties for design purposes: seamless pressure pipes

Type of steel	Grade	Nominal minimum lower yield or 0,2% proof stress N/mm^2											
		Temperature °C											
		50	100	150	200	250	300	350	400	450	500	550	600
Carbon and carbon-manganese	320	172	168	158	147	125	100	91	88	87	—	—	—
	360	192	187	176	165	145	122	111	109	107	—	—	—
	410	217	210	199	188	170	149	137	134	132	—	—	—
	460	241	234	223	212	195	177	162	159	156	—	—	—
	490	256	249	237	226	210	193	177	174	171	—	—	—
1Cr^1/$_2$Mo	440	254	240	230	220	210	183	169	164	161	156	151	—
2^1/$_2$Cr1Mo	410 (*see* Note 1)	121	108	99	92	85	80	76	72	69	66	64	62
	490 (*see* Note 2)	268	261	253	245	236	230	224	218	205	189	167	145
^{1}/$_2$Cr^1/$_2$Mo^1/$_4$V	460	266	259	248	235	218	192	184	177	168	155	148	—

NOTES
1. Annealed condition.
2. Normalised and tempered condition.

Table 6.2.5 Mechanical properties for design purposes: seamless pressure pipes – Estimated values for stress to rupture in 100 000 hours (units N/mm^2)

Temperature °C	Carbon and carbon-manganese		1Cr^1/$_2$Mo	2^1/$_4$Cr1Mo		^{1}/$_2$Cr^1/$_2$Mo^1/$_4$V
	Grade 320 360 410	Grade 460 490	Grade 440	Grade 410 Annealed	Grade 490 Normalised and tempered (*see* Note)	Grade 460
380	171	227	—	—	—	—
390	155	203	—	—	—	—
400	141	179	—	—	—	—
410	127	157	—	—	—	—
420	114	136	—	—	—	—
430	102	117	—	—	—	—
440	90	100	—	—	—	—
450	78	85	—	196	221	—
460	67	73	—	182	204	—
470	57	63	—	168	186	—
480	47	55	210	154	170	218
490	36	47	177	141	153	191
500	—	41	146	127	137	170
510	—	—	121	115	122	150
520	—	—	99	102	107	131
530	—	—	81	90	93	116
540	—	—	67	78	79	100
550	—	—	54	69	69	85
560	—	—	43	59	59	72
570	—	—	35	51	51	59
580	—	—	—	44	44	46

NOTE
When the tempering temperature exceeds 750°C, the values for Grade 410 are to be used.

■ *Section 3*
Welded pressure pipes

3.1 Scope

3.1.1 Provision is made in this Section for welded pressure pipes in carbon, carbon-manganese and low alloy steels.

3.2 Manufacture and chemical composition

3.2.1 Pipes are to be manufactured by the electric resistance or induction welding process and, if required, may be subsequently hot reduced or cold finished.

3.2.2 Where it is proposed to use other welding processes, details of the welding processes and procedures are to be submitted for review.

3.2.3 In all cases, welding procedure tests are required. Test samples are to be subjected to the same heat treatment as the pipe.

3.2.4 The method of deoxidation and the chemical composition of ladle samples are to comply with the appropriate requirements given in Table 6.3.1.

3.3 Heat treatment

3.3.1 Pipes are to be supplied in the heat treated condition given in Table 6.3.3.

3.4 Mechanical tests

3.4.1 All pipes are to be presented in batches as defined in Section 1.

3.4.2 Each pressure pipe selected for test is to be subjected to tensile and flattening or bend tests.

3.4.3 The results of all mechanical tests are to comply with the appropriate requirements given in Table 6.3.2.

3.5 Mechanical properties for design

3.5.1 The mechanical properties at elevated temperature for carbon and carbon-manganese steels in Grades 320 to 460 and 1Cr½Mo steel can be taken from the appropriate Tables in Section 2.

Table 6.3.1 Chemical composition of welded pressure pipes

Type of steel	Grade	Method of deoxidation	Chemical composition of ladle samples %					
			C	Si	Mn	S max.	P max.	Residual elements
Carbon and carbon-manganese	320	Any method (see Note)	≤0,16	—	0,30–0,70	0,050	0,050	Ni 0,30 max. Cr 0,25 max. Mo 0,10 max. Cu 0,30 max. Total 0,70 max.
	360		≤0,17	≤0,35	0,40–1,00	0,045	0,045	
	410	Killed	≤0,21	≤0,35	0,40–1,20	0,045	0,045	
	460		≤0,22	≤0,35	0,80–1,40	0,045	0,045	
1Cr½Mo	440	Killed	0,10–0,18	0,10–0,35	0,40–0,70	0,040	0,040	Ni 0,30 max. Cr 0,70–1,10 Mo 0,45–0,65 Cu 0,25 max. Sn 0,03 max. Al ≤0,020

NOTE
For rimming steels, the carbon content may be increased to 0,19% max.

Table 6.3.2 Mechanical properties for acceptance purposes: welded pressure pipes

Type of steel	Grade	Yield stress N/mm^2	Tensile strength N/mm^2	Elongation on $5,65\sqrt{S_o}$ % minimum	Flattening test constant *C*
Carbon and carbon-manganese	320 360 410 460	195 215 235 265	320 – 440 360 – 480 410 – 530 460 – 580	25 24 22 21	0,10 0,10 0,08 0,07
1Cr$^1/_2$Mo	440	275	440 – 590	22	0,07

Table 6.3.3 Heat treatment: welded pressure pipes

Type of steel	Condition of supply
Carbon and carbon-manganese, *see* Note	Normalised (Normalised and tempered at the option of the manufacturer)
1Cr$^1/_2$Mo	Normalised and tempered
NOTE Subject to special approval, electric resistance welded (ERW) pipes and tubes in grades 320 and 360 may be supplied without heat treatment for the following applications: (a) Class 2 piping systems, except for liquefied gases or other low temperature applications. (b) Class 3 piping systems.	

■ *Section 4*

Ferritic steel pressure pipes for low temperature service

4.1 Scope

4.1.1 Provision is made in this Section for carbon, carbon-manganese and nickel pipes intended for use in the piping arrangements for liquefied gases where the design temperature is less than 0°C. These requirements are also applicable for other types of pressure piping systems where the use of steels with guaranteed impact properties at low temperatures is required.

4.2 Manufacture and chemical composition

4.2.1 Carbon and carbon-manganese steel pipes are to be manufactured by a seamless, electric resistance or induction welding process.

4.2.2 Nickel steel pipes are to be manufactured by a seamless process.

4.2.3 Seamless pipes may be hot finished or cold finished. Welded pipes may be as-welded, hot finished or cold finished. The terms 'hot finished', 'cold finished' and 'as-welded' apply to the condition of the pipes before final heat treatment.

4.2.4 The method of deoxidation and the chemical composition of ladle samples are to comply with the appropriate requirements given in Table 6.4.1.

4.3 Heat treatment

4.3.1 Pipes are to be supplied in the condition given in Table 6.4.3.

4.4 Mechanical tests

4.4.1 All pipes are to be presented for test in batches as defined in Section 1 for Class 1 pressure piping systems, but in addition the material in each batch is to be from the same cast.

4.4.2 At least two per cent of the number of lengths in each batch is to be selected at random for the preparation of tests.

4.4.3 Each pressure pipe selected for test is to be subjected to tensile, flattening or bend test at room temperature and, where the wall thickness is 6 mm or greater, an impact test at the test temperature specified in Table 6.4.2.

4.4.4 The impact tests are to consist of a set of three Charpy V-notch test specimens cut in the longitudinal direction with the notch perpendicular to the original surface of the pipe. The dimensions of the test specimens are to be in accordance with the requirements of Chapter 2.

4.4.5 The results of all tensile, flattening and bend tests are to comply with the appropriate values in Table 6.4.2.

4.4.6 The average value for impact test specimens is to comply with the appropriate requirements of Table 6.4.2. One individual value may be less than the required average value provided that it is not less than 70 per cent of this value. *See* Ch 2,1.4.1 for re-test procedures.

Table 6.4.1 Chemical composition

Type of steel	Grade	Method of deoxidation	Chemical composition of ladle sample %							
			C max.	Si	Mn	P max.	S max.	Ni	Al_{sol} *see* Note	Residual elements
Carbon	360	Fully killed	0,17	0,10—0,35	0,40—1,00	0,030	0,025	—	0,015 min.	Cr 0,25 Cu 0,30 Mo 0,10 Ni 0,30 Total 0,70
Carbon-manganese	410 and 460		0,20	0,10—0,35	0,60—1,40	0,030	0,025	—	0,015 min.	
3 1/2Ni	440		0,15	0,15—0,35	0,30—0,90	0,025	0,020	3,25—3,75	—	Cr 0,25 Cu 0,30 Mo 0,10 Total 0,60
9Ni	690		0,13	0,15—0,30	0,30—0,90	0,025	0,020	8,50—9,50	—	

NOTE
Where a minimum Al_{sol} of 0,015% is specified, the determination of the total aluminium is acceptable provided that the result is not less than 0,020%.

Table 6.4.2 Mechanical properties for acceptance purposes

Type of steel	Grade	Yield stress N/mm^2	Tensile strength N/mm^2	Elongation on $5,65\sqrt{S_o}$ % minimum	Flattening test constant C	Bend test diameter of former (t = thickness)	Charpy V-notch impact tests	
							Test temperature °C	Average energy J minimum
Carbon	360	210	360—480	24	0,10	4t	–40	27
Carbon-manganese	410 460	235 260	410—530 460—580	22 21	0,08 0,07	4t	–50	27
3 1/2Ni	440	245	440—590	16	0,08	4t	–95	34
9Ni	690	510	690—840	15	0,08	4t	–196	41

For standard subsidiary impact test specimens, the minimum energy values are to be as follows:

Required average energy value for standard 10 mm x 10 mm	Subsidiary 10 mm x 7,5 mm	Subsidiary 10 mm x 5 mm
	Average energy	Average energy
27 J	22 J	18 J
34 J	28 J	23 J
41 J	34 J	27 J

Table 6.4.3 Heat treatment

Type of steel	Condition of supply
Carbon and carbon-manganese	Hot finished Normalised Normalised and tempered
3 1/2 Ni	Normalised Normalised and tempered
9Ni	Double normalised and tempered Quenched and tempered

Section 5
Austenitic stainless steel pressure pipes

5.1 Scope

5.1.1 Provision is made in this Section for austenitic stainless steel pipes suitable for use in the construction of the piping systems for chemicals and for liquefied gases where the design temperature is not less than minus 165°C and for bulk chemical tankers.

5.1.2 Austenitic stainless steels are also suitable for service at elevated temperatures. Where such applications are proposed, details of the chemical composition, heat treatment and mechanical properties are to be submitted for consideration and approval.

5.1.3 Where it is intended to supply seamless pipes in the direct quenched condition, a programme of tests for approval is to be carried out under the supervision of the Surveyors, and the results are to be to the satisfaction of LR, *see* Ch 1,2.2.

5.2 Manufacture and chemical composition

5.2.1 Pipes are to be manufactured by a seamless or a continuous automatic electric fusion welding process.

5.2.2 Welding is to be in a longitudinal direction, with or without the addition of filler metal.

5.2.3 The chemical composition of the ladle samples is to comply with the appropriate requirements of Table 6.5.1.

5.3 Heat treatment

5.3.1 Pipes are generally to be supplied by the manufacturer in the solution treated condition over their full length.

5.3.2 Alternatively, seamless pipes may be direct quenched immediately after hot forming, while the temperature of the pipes is not less than the specified minimum solution treatment temperature.

5.4 Mechanical tests

5.4.1 All pipes are to be presented in batches as defined in Section 1 for Class I and II piping systems.

5.4.2 Each pipe selected for test is to be subjected to tensile and flattening or bend tests.

5.4.3 The results of all mechanical tests are to comply with the appropriate requirements given in Table 6.5.2.

Table 6.5.1 Chemical composition

Type of steel	Grade	Chemical composition of ladle sample %								
		C max.	Si	Mn	P max.	S max.	Cr	Mo	Ni	Others
304L	490	0,03	<1,00	<2,00	0,045	0,030	17,0 – 19,0	—	9,0 – 13,0	—
316L	490	0,03	<1,00	<2,00	0,045	0,030	16,0 – 18,5	2,0–3,0	11,0 – 14,5	—
321	510	0,08	<1,00	<2,00	0,045	0,030	17,0 – 19,0	—	9,0 – 13,0	Ti ≥5 x C ≤0,80
347	510	0,08	<1,00	<2,00	0,045	0,030	17,0 – 19,0	—	9,0 – 13,0	Nb ≥10 x C ≤1,00

Table 6.5.2 Mechanical properties for acceptance purposes

Type of steel	Grade	0,2% proof stress N/mm^2 (*see* Note)	1,0% proof stress N/mm^2	Tensile strength N/mm^2	Elongation on $5,65\sqrt{S_o}$ % minimum	Flattening test constant *C*	Bend test diameter of former (*t* = thickness)
304L	490	175	205	490 – 690	30	0,09	3*t*
316L	490	185	215	490 – 690	30	0,09	3*t*
321	510	195	235	510 – 710	30	0,09	3*t*
347	510	205	245	510 – 710	30	0,09	3*t*

NOTE
The 0,2% proof stress values given for information purposes and unless otherwise agreed are not required to be verified by test.

5.5 Intergranular corrosion tests

5.5.1 For materials used for piping systems for chemicals, intercrystalline corrosion tests are to be carried out on one per cent of the number of pipes in each batch, with a minimum of one pipe.

5.5.2 For pipes with an outside diameter not exceeding 40 mm, the test specimens are to consist of a full cross-section. For larger pipes, the test specimens are to be cut as circumferential strips of full wall thickness and having a width of not less than 12,5 mm. In both cases, the total surface area is to be between 15 and 35 cm^2.

5.5.3 Unless otherwise agreed or required for a particular chemical cargo, the testing procedure is to be in accordance with Ch 2,9.

5.5.4 After immersion, the full cross-section test specimens are to be subjected to a flattening test in accordance with the requirements of Chapter 2. The strip test specimens are to be subjected to a bend test through 90° over a mandrel of diameter equal to twice the thickness of the test specimen.

5.6 Fabricated pipework

5.6.1 Fabricated pipework is to be produced from material manufactured in accordance with 5.2, 5.3, 5.4 and 5.5.

5.6.2 Welding is to be carried out in accordance with an approved and qualified procedure by suitably qualified welders.

5.6.3 Fabricated pipework may be supplied in the as-welded condition without subsequent solution treatment provided that welding procedure tests have demonstrated satisfactory material properties including resistance to intercrystalline corrosion.

5.6.4 In addition, butt welds are to be subjected to 5 per cent radiographic examination for Class I, and 2 per cent for Class II pipes.

5.6.5 Fabricated pipework in the as-welded condition and intended for systems located on deck is to be protected by a suitable corrosion control coating.

5.7 Certification of materials

5.7.1 Each test certificate is to be of the type and give the information detailed in Ch 1,3.1 together with general details of heat treatment and, where applicable, the results obtained from intercrystalline corrosion tests. As a minimum, the chemical composition is to include the content of all the elements detailed in Table 6.5.1.

■ *Section 6* Boiler and superheater tubes

6.1 Scope

6.1.1 Provision is made in this Section for boiler and superheater tubes in carbon, carbon-manganese and low alloy steels.

6.1.2 Austenitic stainless steels may also be used for this type of service. Where such applications are proposed, details of the chemical composition, heat treatment and mechanical properties are to be submitted for consideration and approval.

6.2 Manufacture and chemical composition

6.2.1 Tubes are to be seamless or welded and are to be manufactured in accordance with the requirements of Sections 2 and 3, respectively.

6.2.2 The method of deoxidation and the chemical composition of ladle samples are to comply with the requirements given in Table 6.2.1 or 6.3.1, as appropriate.

6.3 Heat treatment

6.3.1 All tubes are to be supplied in accordance with the requirements given in Table 6.2.3 or 6.3.3 as appropriate, except that 1Cr$^1/_2$Mo steel may be supplied in the normalised only condition when the carbon content does not exceed 0,15 per cent.

6.4 Mechanical tests

6.4.1 Tubes are to be presented for test in batches as defined in Section 1.

6.4.2 Each boiler and superheater tube selected for test is to be subjected to at least the following:
(a) Tensile test.
(b) Flattening or bending test.
(c) Expanding or flanging test.

6.4.3 The results of all mechanical tests are to comply with the appropriate requirements given in Table 6.6.1.

6.5 Mechanical properties for design

6.5.1 The mechanical properties at elevated temperature for carbon and carbon-manganese steels in Grades 320 to 460, 1Cr$^1/_2$Mo and 2$^1/_4$Cr1Mo steels can be taken from the appropriate Tables in Section 2.

6.5.2 Where rimming steel is used, the design temperature is limited to 400°C.

Table 6.6.1 Mechanical properties for acceptance purposes: boiler and superheater tubes

Type of steel	Grade	Yield stress N/mm^2	Tensile strength N/mm^2	Elongation on $5{,}65\sqrt{S_o}$ % minimum	Flattening test constant *C*	Bend test diameter of former (*t* = thickness)	Drift expanding and flanging test minimum % increase in outside diameter		
							Ratio $\frac{\text{Inside diameter}}{\text{Outside diameter}}$		
							≤0,6	>0,6 ≤0,8	>0,8
Carbon and carbon-manganese	320 360 410 460	195 215 235 265	320–440 360–480 410–530 460–580	25 24 22 21	0,10 0,10 0,08 0,07	4*t*	12 12 10 8	15 15 12 10	19 19 17 15
1Cr$^1/_2$Mo	440	275	440–590	22	0,07	4*t*	8	10	15
2$^1/_2$Cr1Mo	410 (*see* Note 1) 490 (*see* Note 2)	135 275	410–560 490–640	20 16	0,07	4*t*	8	10	15

NOTES
1. Annealed condition.
2. Normalised and tempered condition.

Section

Section 1 General requirements

1.1 Scope

1.1.1 This Section gives the general requirements for both grey (flake) and spheroidal (nodular) graphite iron castings intended for use in the construction of ships, other marine structures, machinery, boilers, pressure vessels and piping systems.

1.1.2 Where required by the relevant Rules dealing with design and construction, castings are to be manufactured and tested in accordance with Chapters 1 and 2, together with the requirements given in this Section and either Section 2 for grey iron castings or Section 3 for spheroidal graphite iron castings. Castings for crankshafts are additionally to comply with the requirements detailed in Section 4.

1.1.3 As an alternative to 1.1.2, castings which comply with National or proprietary specifications may be accepted, provided that these specifications give reasonable equivalence to the requirements of this Chapter or alternatively are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

1.1.4 Where small castings are produced in large quantities, or where castings of the same type are produced in regular quantities, alternative survey procedures, in accordance with Ch 1,2.2, may be adopted subject to approval by Lloyd's Register (hereinafter referred to as 'LR').

1.2 Manufacture

1.2.1 Castings as designated in 1.1.2 are to be made at foundries approved by LR.

1.2.2 Suitable mechanical methods are to be employed for the removal of surplus material from castings. Thermal cutting processes are not acceptable, except as a preliminary operation to mechanical methods.

1.3 Quality of castings

1.3.1 Castings are to be free from surface or internal defects which would be prejudicial to their proper application in service. The surface finish is to be in accordance with good practice and any specific requirements of the approved plan.

1.4 Chemical composition

1.4.1 The chemical composition of the iron used is left to the discretion of the manufacturer, who is to ensure that it is suitable to obtain the mechanical properties specified for the castings.

1.5 Heat treatment

1.5.1 Except as required by 1.5.2, castings may be supplied in either the as cast or heat treated condition.

1.5.2 For some applications, such as elevated temperature service, or where dimensional stability is important, castings may require to be given a suitable tempering or stress relieving heat treatment. This is to be carried out after any refining heat treatment and before machining.

1.5.3 Where it is proposed to carry out local hardening of the surface of a casting, full details of the proposed procedure are to be submitted for approval.

1.6 Test material

1.6.1 At least one test sample is to be provided for each casting or batch of castings. For large castings, where more than one ladle of metal is used, one test sample is to be provided, from each ladle used.

1.6.2 A batch testing procedure may be adopted for castings with a fettled mass of 1 tonne or less. All castings in a batch are to be of similar type and dimensions, and cast from the same ladle of metal. One test sample is to be provided for each multiple of two tonnes of fettled castings in the batch.

1.6.3 Where separately cast test samples are used, they are to be cast in moulds made from the same type of material as used for the castings and are not to be stripped from the moulds until the temperature is below 500°C.

1.6.4 All test samples are to be suitably marked to identify them with the castings which they represent.

1.6.5 Where castings are supplied in the heat treated condition, the test samples are to be heat treated together with the castings which they represent. For cast-on test samples, the sample is not to be separated from the casting until after heat treatment.

1.7 Mechanical tests

1.7.1 One tensile specimen is to be prepared from each test sample. The dimensions of the test specimens and the testing procedures used are to be in accordance with Chapter 2.

1.7.2 The results of all tensile tests are to comply with the requirements given in Section 2, 3 or 4, as appropriate.

1.7.3 In the case of castings supplied in the as cast condition which initially do not meet the requirements of 1.7.2, the manufacturer, by agreement with the purchaser, has the right to heat treat the castings, together with the representative test samples, and re-submit them for acceptance.

1.7.4 In the case of a batch of castings supplied in the heat treated condition which initially do not meet the requirements of 1.7.2, the manufacturer has the right to re-heat treat the batch together with the representative test samples, and re-submit the castings for acceptance. The number of reheat treatments and retestings will be restricted to two.

1.8 Visual and non-destructive examination

1.8.1 All castings are to be cleaned and adequately prepared for examination. The surfaces are not to be hammered, peened or treated in any way which may obscure defects.

1.8.2 The accuracy and verification of dimensions are the responsibility of the manufacturer, unless otherwise agreed.

1.8.3 All castings are to be presented to the Surveyor for visual examination and this is to include the examination of internal surfaces where applicable.

1.8.4 The non-destructive examination of castings is not required unless otherwise stated in the approved plan or where there is reason to suspect the soundness of the casting.

1.8.5 In the event of any casting proving defective during subsequent machining or testing it is to be rejected notwithstanding any previous certification.

1.9 Rectification of defective castings

1.9.1 At the discretion of the Surveyor, small surface blemishes may be removed by local grinding.

1.9.2 Subject to the prior approval of the Surveyor, castings containing local porosity may be rectified by vacuum impregnation with a suitable plastic filler, provided that the extent of the porosity is such that it does not adversely affect the strength of the casting.

1.9.3 Repairs by welding are not permitted on grey cast iron parts and generally not permitted for spheroidal or nodular graphite iron castings, but may be considered in special circumstances for spheroidal or nodular graphite iron castings. In such cases, full details of the proposed repair procedure are to be submitted for approval prior to the commencement of the proposed rectification.

1.10 Pressure testing

1.10.1 When required by the relevant Rules, castings are to be pressure tested before final acceptance. These tests are to be carried out in the presence and to the satisfaction of the Surveyor.

1.11 Identification of castings

1.11.1 The manufacturer is to adopt a system of identification which will enable all finished castings to be traced to the original cast, and the Surveyor is to be given full facilities for tracing the castings when required.

1.11.2 Before acceptance, all castings which have been tested and inspected with satisfactory results are to be clearly marked by the manufacturer with the following particulars:
(a) Type and grade of cast iron.
(b) Identification number, cast number or other marking which will enable the full history of the casting to be traced.
(c) Manufacturer's name or trade mark.
(d) LR or Lloyd's Register and the abbreviated name of LR's local office.
(e) Personal stamp of Surveyor responsible for inspection.
(f) Test pressure, where applicable.
(g) Date of final inspection.

1.11.3 Where small castings are manufactured in large numbers, modified arrangements for identification may be specially agreed with the Surveyor.

1.12 Certification of materials

1.12.1 A LR certificate is to be issued, *see* Ch 1,3.1.

1.12.2 The manufacturer is to provide the Surveyor with a written statement giving the following particulars for each casting or batch of castings which has been accepted:
(a) Purchaser's name and order number.
(b) Description of castings and quality of cast iron.
(c) Identification number.
(d) General details of heat treatment, where applicable.
(e) Results of mechanical tests.
(f) Test pressure, where applicable.
(g) When specially required, the chemical analysis of ladle samples.

1.12.3 Where applicable, the manufacturer is to provide a signed statement regarding non-destructive testing as required by 1.8, together with a statement and/or a sketch detailing the extent and position of all weld repairs made to each casting as required by 1.9.

Section 2
Grey iron castings

2.1 Scope

2.1.1 This Section gives the specific requirements for grey cast iron castings.

2.2 Test material

2.2.1 Separately cast test samples in the form of cylindrical bars, 30 mm diameter and of a suitable length, are to be used unless otherwise agreed by LR. Test samples of other dimensions may be specially required for some components as may cast-on samples. In these circumstances, the tensile strength requirements are to be agreed.

2.2.2 When two or more test samples are cast simultaneously in a single mould, the bars are to be at least 50 mm apart.

2.2.3 Test samples may be cast integrally when a casting is both more than 20 mm thick and its mass exceeds 200 kg, subject to agreement between the manufacturer and the purchaser. The type and location of the samples are to be such as to provide approximately the same cooling conditions as for the casting it represents and are also subject to agreement.

2.2.4 For continuous melting of the same grade of cast iron in large tonnages the mass of a batch may be taken as the output of two hours of pouring.

2.2.5 Where 2.2.4 applies and production is carefully monitored by systematic checking of the melting process by, for example, chill testing, chemical analysis or thermal analysis, test samples may be taken at longer intervals as agreed by the Surveyor.

2.3 Mechanical tests

2.3.1 Only the tensile strength is to be determined, and the results obtained from tests are to comply with the minimum value specified for the castings being supplied. Except for crankshaft castings (*see* Section 4), the specified tensile strength is to be not less than 200 N/mm^2 subject to any additional requirements of the relevant Rules. The fractured surfaces of all tensile test specimens are to be granular and entirely grey in appearance.

Section 3
Spheroidal or nodular graphite iron castings

3.1 Scope

3.1.1 This Section gives the specific requirements for spheroidal or nodular graphite iron castings.

3.1.2 These requirements are generally applicable to castings intended for use at ambient temperatures. Additional requirements will be necessary when the castings are intended for service at either low or elevated temperatures. Impact test requirements are given for low temperature service in 3.4.2.

3.2 Heat treatment

3.2.1 The special qualities with 350 N/mm^2 and 400 N/mm^2 nominal tensile strength and impact test are to undergo a ferritising heat treatment, *see* 3.4.2.

3.3 Test material

3.3.1 The test samples are to be as detailed in Figs. 7.3.1, 7.3.2 or 7.3.3 The dimensions of the test specimens and testing procedures used are to be in accordance with Chapter 2. Test samples of other dimensions may be specially required for some castings and these are to be agreed with the Surveyor.

3.3.2 The test samples may be either gated to the casting or separately cast.

3.3.3 Where separately cast test samples are used, they are to be taken towards the end of pouring of the castings.

3.4 Mechanical tests

3.4.1 The tensile strength and elongation are to be determined and are to comply with the requirements of Table 7.3.1. Minimum values for the 0,2 per cent proof stress are also included in this Table but are to be determined only if included in the specification. Typical ranges of hardness values are also given in Table 7.3.1 and are intended for information purposes.

3.4.2 Impact tests may be required for some applications in which case the selection of the grade is to be confined to those listed in Table 7.3.2. These castings are to be given a ferritising heat treatment. The mechanical test results are to comply with Table 7.3.2.

3.4.3 Castings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Tables 7.3.1 and 7.3.2 but subject to any additional requirements of the relevant Rules.

3.5 Metallographic examination

3.5.1 Samples for metallographic examination are to be prepared for spheroidal or nodular graphite iron castings. These samples are to be representative of each ladle used and may conveniently be taken from the tensile test specimens. Alternative arrangements for the provision of these samples may, however, be adopted subject to the concurrence of the Surveyor. They are, however, to be taken towards the end of the pour.

Dimension	Standard sample, mm	Alternative samples when specially required, mm		
u *v* *x* *y*	25 55 40 100	12 40 30 80	50 90 60 150	75 125 65 165
Z *Rs*	To suit testing machine Approximately 5			

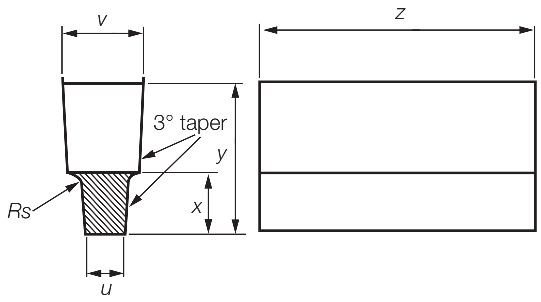


Fig. 7.3.1 Type A (U-type) test samples

Dimension	Standard sample, mm
u *v* *x* *y*	25 90 40 100
Z *Rs*	To suit testing machine Approximately 5

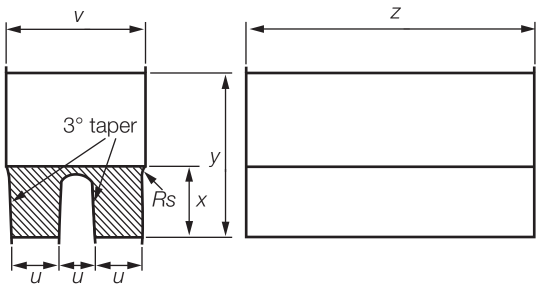


Fig. 7.3.2 Type B (Double U-type) test samples

3.5.2 Examination of the samples is to show that at least 90 per cent of the graphite is in a dispersed spheroidal or nodular form. Details of typical matrix structures are given in Table 7.3.1 and are intended for information purposes.

Dimension	Standard sample, mm	Alternative samples when specially required, mm		
u *v* *x* *y*	25 55 40 140	12 40 25 135	50 100 50 150	75 125 65 175
Z	To suit testing machine			
Minimum thickness of mould surrounding test sample	40	40	80	80

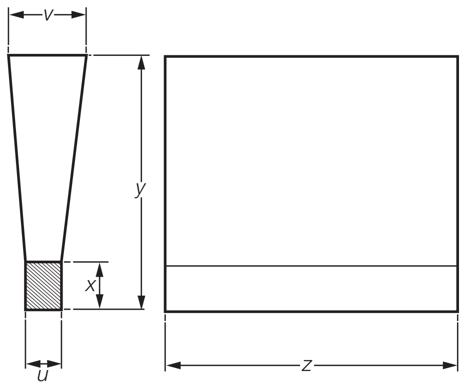


Fig. 7.3.3 Type C (Y-type) test samples

Table 7.3.1 Mechanical properties for acceptance purposes: spheroidal or nodular graphite iron castings

Specified minimum tensile strength N/mm^2	0,2% proof stress (*see* Note) N/mm^2 minimum	Elongation on $5,65\sqrt{S_o}$ % minimum	Typical hardness value HB (*see* 3.4.1)	Typical structure of matrix (*see* 3.5.1)
370	230	17	120 – 180	Ferrite
400	250	12	140 – 200	Ferrite
500	320	7	170 – 240	Ferrite/pearlite
600	370	3	190 – 270	Pearlite/ferrite
700	420	2	230 – 300	Pearlite
800	480	2	250 – 350	Pearlite or tempered structure

NOTE
Proof stresses need only be determined if specifically requested.

Table 7.3.2 Mechanical properties: special qualities

Specified minimum tensile strength N/mm^2	0,2% proof stress minimum (*see* Note 1) N/mm^2	Elongation on 5,65 $\sqrt{S_o}$ minimum % (*see* Note 2)	Typical hardness value	Charpy V-notch impact tests	
				Test temperature °C (*see* Note 3)	Average energy J minimum (*see* Note 4)
350	220	22	110 – 170	20 –40	17 (14) 12 (10)
400	250	18	140 – 200	20 –20	14 (11) 12 (10)

NOTES
1. Proof stresses need only be determined if specifically requested.
2. In the case of integrally cast samples, the acceptable elongation may be taken as 2 percentage points less.
3. Tests need only be made at either of the temperatures listed, as appropriate.
4. The average value measured on three Charpy V-notch specimens. One of the three values may be below the specified minimum average value, but not less than the value shown in brackets.
5. Typical structure of the matrix is ferrite.

■ *Section 4* Iron castings for crankshafts

4.1 Scope

4.1.1 This Section gives additional requirements for cast iron crankshafts intended for diesel engines and compressors. For both of these applications, details of the proposed specification are to be submitted for approval.

4.1.2 Crankshaft castings in grey iron are acceptable only for compressors, and the specified minimum tensile strength is to be not less than 300 N/mm^2.

4.1.3 For crankshaft castings in spheroidal or nodular graphite iron, the specified minimum tensile strength is to be not less than 370 N/mm^2.

4.2 Manufacture

4.2.1 Details of the method of manufacture, including the arrangements proposed for the provision of test material, are to be submitted for approval.

4.2.2 Tests to demonstrate the soundness of prototype castings and the mechanical properties at important locations will be required.

4.3 Heat treatment

4.3.1 In general, crankshaft castings other than those which are fully annealed, normalised or oil quenched and tempered, are to receive a suitable stress relief heat treatment before machining.

4.3.2 Where it is proposed to harden the surfaces of machined pins and/or journals of cast iron crankshafts, details of the process are to be submitted for approval. Before such a process is applied to a crankshaft it is to be demonstrated by procedure tests, and to the satisfaction of the Surveyor, that the process is suitably controlled and does not impair the strength or soundness of the material.

4.4 Test material

4.4.1 Unless otherwise approved, the dimensions of the test samples are to be such as to ensure that they have mechanical properties representative of those of the average section of the crankshaft casting.

4.4.2 For large crankshaft castings, the test samples are to be cast integral with, or gated from, each casting.

4.4.3 The batch testing procedure detailed in 1.6.2 may be adopted only where small and identical crankshaft castings are produced in quantity. Generally, the fettled mass of each casting in a batch is not to exceed 100 kg, and in addition to tensile tests, the hardness of each casting is to be determined. For this purpose, a small flat is to be ground on each crankshaft, and Brinell hardness tests are to be carried out. The results obtained from these tests are to comply with the approved specification.

4.5 Non-destructive examination

4.5.1 Cast crankshafts are to be subjected to a full magnetic particle or dye penetrant examination after final machining and completion of any surface hardening operations.

4.5.2 Particular attention is to be given to the testing of the pins, journals and associated fillet radii.

4.5.3 Cracks and crack-like defects are not acceptable. Fillet radii are to be free from any indications.

4.6 Rectification of defective castings

4.6.1 Cast iron crankshafts are not to be repaired by welding, and blemishes are not to be plugged with a filler.

4.7 Certification of materials

4.7.1 The chemical composition of ladle samples is to be given in addition to the other particulars detailed in 1.12.2.

Section

■ *Section 1* Plates, bars and sections

1.1 Scope

1.1.1 This Section makes provision for aluminium alloy plates, bars and sections intended for use in the construction of ships and other marine structures and for cryogenic applications.

1.1.2 Except as provided in 1.1.4, all items are to be manufactured and tested in accordance with the appropriate requirements of Chapters 1 and 2 and those detailed in this Section.

1.1.3 The thickness of plates, sections and bars described by these requirements will be in the range between 3 and 50 mm. Plates and sections less than 3,0 mm thick may be manufactured and tested in accordance with the requirements of an acceptable national specification.

1.1.4 Plates less than 3,0 mm thick and sections less than 40 mm x 40 mm x 3,0 mm may be manufactured and tested in accordance with the requirements of an acceptable National specification.

1.1.5 Where the section thickness exceeds 50 mm, the requirements will be subject to special consideration.

1.1.6 Materials intended for the construction of cargo tanks or storage for liquefied gases, and for other low temperature applications, are to be manufactured in the 5083 alloy in the annealed condition.

1.1.7 As an alternative to 1.1.2 and 1.1.4, materials which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Section and are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

1.2 Manufacture

1.2.1 Aluminium alloys are to be manufactured at works approved by Lloyd's Register (hereinafter referred to as 'LR').

1.2.2 The alloys may be cast either in ingot moulds or by an approved continuous casting process. Plates are to be formed by rolling and may be hot or cold finished. Bars and sections may be formed by extrusion, rolling or drawing.

1.2.3 All melts are to be suitably degassed prior to casting such that the aim hydrogen content is less than 0,2 ml per 100 g.

1.3 Quality of materials

1.3.1 Materials are to be free from surface or internal defects of such a nature as would be harmful in service.

1.3.2 The manufacturer is to verify the integrity of pressure welds of closed extrusion profiles in accordance with 1.10.

Table 8.1.1 Underthickness tolerances for rolled products for marine construction

Nominal thickness range, mm	Underthickness tolerance for nominal width range, mm		
	≤1500	>1500 ≤2000	>2000 ≤3500
≥3,0 <4,0	0,10	0,15	0,15
≥4,0 <8,0	0,20	0,20	0,25
≥8,0 <12	0,25	0,25	0,25
≥12 <20	0,35	0,40	0,50
≥20 <50	0,45	0,50	0,65

1.4 Dimensional tolerances

1.4.1 Underthickness tolerances for rolled products for marine construction are given in Table 8.1.1.

1.4.2 Underthickness tolerances for extruded products are to comply with an acceptable National or International Standard.

1.4.3 There are to be no underthickness tolerances for materials for application in cryogenic process pressure vessels.

1.4.4 Dimensional tolerances other than permitted underthicknesses are to comply with an acceptable National or International Standard.

1.4.5 Verification of dimensions is the responsibility of the manufacturer. Acceptance by Surveyors of material which is later found to be defective does not absolve the manufacturer from this responsibility.

Table 8.1.2 Chemical composition, percentage

Element	5083	5383	5059	5086	5754	5456	6005–A (*see* Note 1)	6061 (*see* Note 1)	6082
Copper	0,10 max.	0,20 max.	0,25 max.	0,10 max.	0,10 max.	0,10 max.	0,30 max.	0,15—0,40	0,10 max.
Magnesium	4,0—4,9	4,0—5,2	5,0—6,0	3,5—4,5	2,6—3,6	4,7—5,5	0,40—0,70	0,80—1,20	0,60—1,20
Silicon	0,40 max.	0,25 max.	0,45 max.	0,40 max.	0,40 max.	0,25 max.	0,50—0,90	0,40—0,80	0,70—1,30
Iron	0,40 max.	0,25 max.	0,50 max.	0,50 max.	0,40 max.	0,40 max.	0,35 max.	0,70 max.	0,50 max.
Manganese	0,40—1,00	0,7—1,0	0,6—1,2	0,20—0,70	0,50 max. (*see* Note 2)	0,50—1,00	0,50 max. (*see* Note 3)	0,15 max.	0,40—1,00
Zinc	0,25 max.	0,40 max.	0,40—0,90	0,25 max.	0,20 max.	0,25 max.	0,20 max.	0,25 max.	0,20 max.
Chromium	0,05—0,25	0,25 max	0,25 max.	0,05—0,25	0,30 max. (*see* Note 2)	0,05—0,20	0,30 max. (*see* Note 3)	0,04—0,35	0,25 max.
Titanium	0,15 max.	0,15 max.	0,20 max.	0,15 max.	0,15 max.	0,20 max.	0,10 max.	0,15 max.	0,10 max.
Zirconium		0,20 max.	0,05—0,25						
Other elements: each	0,05 max.	0,05 max.	0,05 max.	0,05 max.	0,05 max.	0,05 max.	0,05 max.	0,05 max.	0,05 max.
total	0,15 max.	0,15 max.	0,15 max.	0,15 max.	0,15 max.	0,15 max.	0,15 max.	0,15 max.	0,15 max.

NOTES
1. These alloys are not normally acceptable for application in direct contact with sea-water.
2. Mn + Cr = 0,10 min., 0,60 max.
3. Mn + Cr = 0,12 min., 0,50 max.

1.5 Chemical composition

1.5.1 Samples for chemical analysis are to be taken representative of each cast, or the equivalent where a continuous melting process is involved.

1.5.2 The chemical composition of these samples is to comply with the requirements of Table 8.1.2.

1.6 Heat treatment

1.6.1 The Aluminium 5000 series alloys, capable of being strain hardened, are to be supplied in any of the following temper conditions:

- O annealed
- H111 annealed with slight strain hardening
- H112 strain hardened from working at elevated temperatures
- H116 strain hardened and with specified resistance to exfoliation corrosion for alloys where the magnesium content is 4 per cent or more
- H321 strain hardened and stabilised.

1.6.2 The H116 temper is specially developed for use in a marine environment.

1.6.3 The Aluminium 6000 series alloys, capable of being age hardened, are to be supplied in either of the following temper conditions:

- T5 hot worked and artificially aged
- T6 solution treated and artificially aged.

1.7 Test material

1.7.1 Materials of the same product form, (i.e., plates, sections or bars) and thickness and from a single cast or equivalent, are to be presented for test in batches of not more than 2 tonnes, with the exceptions of those given in 1.7.2, 1.7.3 and 1.7.4.

1.7.2 For single plates or coils weighing more than 2 tonnes, only one tensile specimen per plate or coil is to be taken.

1.7.3 A tensile test specimen is required from each plate to be used in the construction of cargo tanks, secondary barriers and process pressure vessels with design temperatures below –55°C.

1.7.4 Extrusions, bars and sections of less than 1 kg/m in nominal weight are to be tested in batches of 1 tonne. Where the nominal weight is greater than 5 kg/m, one tensile test is to be carried out for every three tonnes produced, or fractions thereof.

1.7.5 If the material is supplied in the heat treated condition, each batch is to be treated together in the same furnace or subjected to the same finishing treatment when a continuous furnace is used.

1.7.6 For plates over 300 mm in width, tensile test specimens are to be cut with their length transverse to the principal direction of rolling. For narrow plates and for sections and bars, the test specimens are to be cut in the longitudinal direction. Longitudinal tensile test specimens are accepted for the strain hardenable 5000 series alloys.

Table 8.1.3 Minimum mechanical properties for acceptance purposes of selected rolled aluminium alloy products

Alloy and temper condition, *see* Note 3	Thickness, t, mm	0,2% proof stress R_p, N/mm^2	Tensile strength R_m N/mm^2	Elongation 4d, %	Elongation on $5{,}65\sqrt{S_o}$ 5d,%
5083-O	$3 \leq t \leq 50$ (*see* Note 2)	125	275–350	16	14
5083-H111	$3 \leq t \leq 50$	125	275–350	16	14
5083-H112	$3 \leq t \leq 50$	125	275	12	10
5083-H116	$3 \leq t \leq 50$	215	305	10	10
5083-H321	$3 \leq t \leq 50$	215–295	305–380	12	10
5086-O	$3 \leq t \leq 50$	100	240–305	16	14
5086-H111	$3 \leq t \leq 50$	100	240–305	16	14
5086-H112	$3 \leq t \leq 12{,}5$ $12{,}5 < t \leq 50$	125 105	250 240	8 —	— 9
5086-H116	$3 \leq t \leq 50$	195	275	10 (*see* Note 1)	9
5059-O	$3 \leq t \leq 50$	160	330	24	24
5059-H111	$3 \leq t \leq 50$	160	330	24	24
5059-H116	$3 \leq t \leq 20$ $20 < t \leq 50$	270 260	370 360	10 10	10 10
5059-H321	$3 \leq t \leq 20$ $20 < t \leq 50$	270 260	370 360	10 10	10 10
5383-O	$3 \leq t \leq 50$	145	290	17	17
5383-H111	$3 \leq t \leq 50$	145	290	17	17
5754-H111	$3 \leq t \leq 50$	80	190–240	18	17
5383-H116	$3 \leq t \leq 50$	220	305	10	10
5383-H321	$3 \leq t \leq 50$	220	305	10	10
5456-O	$3 \leq t \leq 6{,}3$ $6{,}3 \leq t \leq 50$	130–205 125–205	290–365 285–360	16 16	— 14
5456-H116	$3 \leq t \leq 30$ $30 < t \leq 40$ $40 < t \leq 50$	230 215 200	315 305 285	10 — —	10 10 10
5456-H321	$3 \leq t \leq 12{,}5$ $12{,}5 \leq t \leq 40$ $40 \leq t \leq 50$	230–315 215–305 200–295	315–405 305–385 285–370	12 — —	— 10 10
5754-O	$3 \leq t \leq 50$	80	190–240	18	17

NOTES
1. 8% for thickness up to and including 6,3 mm.
2. For application to liquefied natural gas carriers or liquefied natural gas tankers where thicknesses are in excess of 50 mm, the mechanical properties given in this table are, in general, to be complied with.
3. The mechanical properties for the O and H111 tempers are the same for all alloys shown in this Table. However, they are separated in this Table as they are made using different manufacturing processes.

Table 8.1.4 Minimum mechanical properties for acceptance purposes of selected extruded aluminium alloy products

Alloy and temper condition, *see* Note 2	Thickness, t, mm	0,2% proof stress R_p, N/mm^2	Tensile strength R_m N/mm^2	Elongation 4d, %	Elongation on $5{,}65\sqrt{S_o}$ 5d,%
5083-O	$3 \le t \le 50$	110	270–350	14	12
5083-H111	$3 \le t \le 50$	165	275	12	10
5083-H112	$3 \le t \le 50$	110	270	12	10
5086-O	$3 \le t \le 50$	95	240–315	14	12
5086-H111	$3 \le t \le 50$	145	250	12	10
5086-H112	$3 \le t \le 50$	95	240	12	10
5059-H112	$3 \le t \le 50$	200	330	10	10
5383-O	$3 \le t \le 50$	145	290	17	17
5383-H111	$3 \le t \le 50$	145	290	17	17
5383-H112	$3 \le t \le 50$	190	310	13	13
6005A-T5	$3 \le t \le 50$	215	260	9	8
6005A-T6	$3 \le t \le 10$ $10 < t \le 50$	215 200	260 250	8 8	6 6
6061-T6	$3 \le t \le 50$	240	260	10	8
6082-T5	$3 \le t \le 50$	230	270	8	6
6082-T6	$3 \le t \le 5$ $5 < t \le 50$	250 260	290 310	6 10	— 8

NOTES
1. The values are applicable for longitudinal and transverse tensile test specimens as well.
2. The mechanical properties for the O and H111 tempers are the same for all alloys shown in this Table. However, they are separated in this Table as they are made using different manufacturing processes.

1.7.7 Longitudinal tensile test specimens from a plate are to be taken at 1/3 width from the longitudinal edge. Longitudinal tensile test specimens taken from extruded sections should be taken in the range from 1/3 to 1/2 of the distance from the edge to the centre of the thickest region of the section.

1.8 Mechanical tests

1.8.1 At least one tensile test specimen is to be prepared from each batch of material submitted for acceptance.

1.8.2 Tensile test specimens are to be machined to the dimensions given in Fig. 2.2.3 in Chapter 2. Alternatively, machined proportional test specimens of circular cross-section in accordance with Fig. 2.2.2 in Chapter 2 may be used provided that the diameter is not less than 10 mm. Round bars may be tested in full section, or test specimens may be machined in accordance with the dimensions given in Fig. 2.2.2 in Chapter 2.

1.8.3 The results of all tensile tests are to comply with the values given in Tables 8.1.3 and 8.1.4, as applicable.

1.9 Corrosion tests

1.9.1 Rolled 5000 series alloys of type 5083, 5383, 5059, 5456 and 5086 in the H111, H112, H116 and H321 tempers intended for use in marine hull construction or in marine applications with frequent direct contact with seawater are to be corrosion tested with respect to exfoliation and intergranular corrosion resistance.

1.9.2 The manufacturer is to establish the relationship between microstructure and resistance to corrosion when the above alloys are approved. A reference photomicrograph taken at 500x under the conditions specified in ASTM B928 Section 9.4.1, is to be prepared for each of the alloy-tempers and thickness ranges relevant. The reference photographs are to be taken from samples which have exhibited no evidence of exfoliation corrosion and a pitting rating of PB or better, when subjected to the test described in ASTM G66 (ASSET).The samples are also to have exhibited resistance to

intergranular corrosion at a mass loss no greater than 15 mg/cm^2, when subjected to the test described in ASTM G67 (NAMLT). Upon satisfactory establishment of the relationship between microstructure and resistance to corrosion, the master photomicrographs and the results of the corrosion tests are to be approved by LR. Production practices are not to be changed after approval of the reference micrographs.

1.9.3 For batch acceptance of 5000 series alloys in the H116 and H321 tempers, metallographic examination of one sample selected from mid width at one end of a coil or random sheet or plate is to be carried out. The micro-structure of the sample is to be compared to the reference photomicrograph of acceptable material in the presence of the Surveyor. A longitudinal section perpendicular to the rolled surface is to be prepared for metallographic examination, under the conditions specified in ASTM B928 Section 9.6.1. If the microstructure shows evidence of continuous grain boundary network of aluminium-magnesium precipitate in excess of the reference photomicrographs of acceptable material, the batch is either to be rejected or tested for exfoliation corrosion resistance and intergranular corrosion resistance subject to the agreement of the Surveyor. The corrosion tests are to be in accordance with ASTM G66 and G67 or equivalent standards. Acceptance criteria are that the sample shall exhibit no evidence of exfoliation corrosion and a pitting rating of PB or better when test subjected to ASTM G66 (ASSET) test, and the sample is to exhibit resistance to intergranular corrosion at a mass loss no greater than 15 mg/cm^2 when subjected to ASTM G67 (NAMLT) test. If the results from testing satisfy the acceptance criteria stated in 1.9.2, the batch is accepted, otherwise it is to be rejected.

1.9.4 As an alternative to metallographic examination, each batch may be tested for exfoliation corrosion resistance and intergranular corrosion resistance, in accordance with ASTM G66 and G67 under the conditions specified in ASTM B298, or equivalent standards. If this alternative is used, then the results of the test must satisfy the acceptance criteria stated in 1.9.2.

1.9.5 Tempers that are corrosion tested in accordance with 1.9.3 are to be marked 'M' after the temper condition, e.g., 5083 H321 M.

1.10 Pressure weld tests

1.10.1 The integrity of pressure welds of closed profile extrusions is to be verified by examination of macrosections or drift expansion tests.

1.10.2 Every closed profile extrusion is to be sampled, except where the closed profile extrusions are equal to or shorter than 6,0 m long, in which case a batch is to comprise five profiles. Every sample is to be tested at both ends after final heat treatment.

1.10.3 Where verification is by examination of macro-sections, no indication of lack of fusion is permitted.

1.10.4 Where verification of fusion at pressure welds of closed profile extrusions is by drift expansion test, testing is to be generally in accordance with Ch 2,4.3. The minimum included angle of the mandrel is to be 60°, and the minimum specimen length, 50 mm. For acceptance, there is to be no failure by a clean split along the weld line.

1.11 Visual and non-destructive examination

1.11.1 Surface inspection and verification of dimensions are the responsibility of the manufacturer, and acceptance by the Surveyors of material later found to be defective shall not absolve the manufacturer from this responsibility.

1.11.2 In general, the non-destructive examination of materials is not required for acceptance purposes. Manufacturers are expected, however, to employ suitable methods of non-destructive examination for the general maintenance of quality standards.

1.11.3 For applications where the non-destructive examination of materials is considered to be necessary, the extent of this examination, together with appropriate acceptance standards, are to be agreed between the purchaser, manufacturer and Surveyor.

1.12 Rectification of defects

1.12.1 Slight surface imperfections may be removed by mechanical means, provided that the prior agreement of the Surveyor is obtained, that the work is carried out to his satisfaction and that the final dimensions are acceptable. The repair of defects by welding is not allowed.

1.13 Identification

1.13.1 The manufacturer is to adopt a system of identification which will ensure that all finished material in a batch presented for test is of the same nominal chemical composition.

1.13.2 Products are to be clearly marked by the manufac-turer in accordance with the requirements of Chapter 1. The following details are to be shown on all materials which have been accepted:

(a) Manufacturer's name or trade mark.
(b) Alloy grade and temper condition.
(c) Identification mark which will enable the full history of the item to be traced.
(d) The stamp of the LR brand, .

1.14 Certification of materials

1.14.1 A manufacturer's certificate validated by LR is to be issued, *see* Ch 1,3.1.

1.14.2 Each test certificate is to include the following particulars:

(a) Purchaser's name and order number.
(b) Contract number.
(c) Address to which material is to be despatched.
(d) Description and dimensions.
(e) Alloy grade and temper condition.
(f) Identification mark which will enable the full history of the item to be traced.
(g) Chemical composition.
(h) Mechanical test results (not required on shipping statement).
(j) Details of temper condition and heat treatment, where applicable.
(k) Corrosion test results (as applicable).

1.14.3 Where the alloy is not produced at the works at which it is wrought, a certificate is to be supplied by the manufacturer of the alloy stating the cast number and chemical composition. The works at which the alloy was produced must be approved by LR.

■ *Section 2* Aluminium alloy rivets

2.1 Scope

2.1.1 Provision is made in this Section for aluminium alloy rivets intended for use in the construction of marine structures.

2.1.2 They are to be manufactured and tested in accordance with the appropriate requirements of Section 1 and those detailed in this Section.

2.2 Chemical composition

2.2.1 The chemical composition of bars used for the manufacture of rivets is to comply with the requirements of Table 8.2.1.

Table 8.2.1 Chemical composition, percentage

Element	5154A	6082
Copper	0,10 max.	0,10 max.
Magnesium	3,1 – 3,9	0,6 – 1,2
Silicon	0,50 max.	0,7 – 1,3
Iron	0,50 max.	0,50 max.
Manganese	0,1 – 0,5	0,4 – 1,0
Zinc	0,20 max.	0,20 max.
Chromium	0,25 max.	0,25 max.
Titanium	0,20 max.	0,10 max.
Other elements: each	0,05 max.	0,05 max.
total	0,15 max.	0,15 max.
Aluminium	Remainder	Remainder

2.3 Heat treatment

2.3.1 Rivets are to be supplied in the following condition:

5154A – annealed
6082 – solution treated.

2.4 Test material

2.4.1 Bars intended for the manufacture of rivets are to be presented for test in batches of not more than 250 kg. The material in each batch is to be the same diameter and nominal chemical composition.

2.4.2 At least one test sample is to be selected from each batch and, prior to testing, is to be heat treated in full cross-section and in a manner simulating the heat treatment applied to the finished rivets.

2.5 Mechanical tests

2.5.1 At least one tensile and one dump test specimen are to be prepared from each test sample.

2.5.2 The tensile test specimen may be either a suitable length of bar tested in full cross-section or a specimen machined to the dimensions given in Fig. 2.2.2 in Chapter 2.

2.5.3 The dump test specimen is to consist of a section cut from the bar with the ends perpendicular to the axis. The length of this section is to be equal to the diameter of the bar.

2.5.4 The results of tensile tests are to comply with the appropriate requirements of Table 8.2.2.

Table 8.2.2 Mechanical properties for acceptance purposes

Mechanical properties	5154A	6082
0,2% proof stress N/mm^2 min.	90	120
Tensile strength N/mm^2 min.	220	190
Elongation on $5{,}65\sqrt{S_o}$ % min.	18	16

2.5.5 The dump test is to be carried out at ambient temperature and is to consist of compressing the specimen until the diameter is increased to 1,6 times the original diameter. After compression, the specimen is to be free from cracks.

2.6 Tests from manufactured rivets

2.6.1 At least three samples are to be selected from each consignment of manufactured rivets. Dump tests as detailed in 2.5 are to be carried out on each sample.

2.7 Identification

2.7.1 Each package of manufactured rivets is to be identified with attached labels giving the following details:
(a) Manufacturer's name or trade mark.
(b) Alloy grade.
(c) Rivet size.

2.8 Certification of materials

2.8.1 A manufacturer's certificate is to be issued (*see* Ch 1,3.1) and for each consignment of manufactured rivets is to include the following particulars:
(a) Purchaser's name and order number.
(b) Description and dimensions.
(c) Specification.

■ *Section 3* Aluminium alloy castings

3.1 Scope

3.1.1 Provision is made in this Section for aluminium alloy castings intended for use in the construction of ships, ships for liquid chemicals and other marine structures and liquefied gas piping systems where the design temperature is not lower than minus 165°C. These materials should not be used for piping systems outside cargo tanks except for short lengths of pipes attached to the cargo tanks in which case fire-resisting insulation should be provided.

3.1.2 Castings are to be manufactured and tested in accordance with Chapters 1 and 2 and also with the requirements of this Section.

3.1.3 As an alternative to 3.1.2, castings which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Section or are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

3.2 Manufacture

3.2.1 Castings are to be manufactured at foundries approved by LR.

3.3 Quality of castings

3.3.1 All castings are to be free from surface or internal defects which would be prejudicial to their proper application in service.

3.4 Chemical composition

3.4.1 The chemical composition of a sample from each cast is to comply with the requirements given in Table 8.3.1. Suitable grain refining elements may be used at the discretion of the manufacturer. The content of such elements is to be reported in the ladle analysis.

Table 8.3.1 Chemical composition, percentage

Alloy / Element	Al–Mg 3	Al–Si 12	Al–Si 10 Mg	Al–Si 7 High purity
Copper	0,1 max.	0,1 max.	0,1 max.	0,1 max.
Magnesium	2,5—4,5	0,1 max.	0,15—0,4	0,25—0,45
Silicon	0,5 max.	11,0—13,5	9,0—11,0	6,5—7,5
Iron	0,5 max.	0,7 max.	0,6 max.	0,2 max.
Manganese	0,6 max.	0,5 max.	0,6 max.	0,1 max.
Zinc	0,2 max.	0,1 max.	0,1 max.	0,1 max.
Chromium	0,1 max.	—	—	—
Titanium	0,2 max.	0,2 max.	0,2 max.	0,2 max.
Others each	0,05 max.	0,05 max.	0,05 max.	0,05 max.
Total	0,15 max.	0,15 max.	0,15 max.	0,15 max.
Aluminium	Remainder	Remainder	Remainder	Remainder

3.4.2 Where it is proposed to use alloys not specified in Table 8.3.1, details of the chemical composition, heat treatment and mechanical properties are to be submitted for approval.

3.4.3 When a cast is wholly prepared from ingots for which an analysis is already available, and provided that no significant alloy additions are made during melting, the ingot maker's certified analysis can be accepted subject to occasional checks as required by the Surveyor.

3.5 Heat treatment

3.5.1 Castings are to be supplied in the following conditions:

Grade Al-Mg 3 – as-manufactured
Grade Al-Si 12 – as-manufactured
Grade Al-Si 10 Mg – as-manufactured or solution heat treated and precipitation hardened
Grade Al-Si 7 Mg (high purity) – solution heat treated and – precipitation hardened.

3.6 Mechanical tests

3.6.1 At least one tensile specimen is to be tested from each cast and, where heat treatment is involved, for each heat treatment batch from each cast. Where continuous melting is employed, 500 kg of fettled castings may be regarded as a cast.

3.6.2 The test samples are to be separately cast in moulds made from the same type of material as used for the castings. These moulds should conform to National Standards.

3.6.3 The method and procedures for the identification of the test specimens, and the castings they represent, are to be agreed with the Surveyor. The identification marks are to be maintained during the preparation of test specimens.

3.6.4 Where castings are supplied in the heat treated condition, the test samples are to be heat treated together with the castings which they represent prior to testing.

3.6.5 The results of all tensile tests are to comply with the appropriate requirements given in Table 8.3.2 and/or Table 8.3.3.

Table 8.3.2 Minimum mechanical properties for acceptance purposes of sand-cast and investment cast reference test pieces

Alloy	Temper (*see* Note)	Tensile strength N/mm^2	Elongation %
Al–Mg 3	M	150	5
Al–Si 12	M	150	3
Al–Si 10 Mg	M	150	2
Al–Si 10 Mg	TF	220	1
Al–Si 7 Mg	TF	230	5

NOTE
M refers to as cast condition.
TF refers to solution heat treated and precipitation hardened condition.

Table 8.3.3 Minimum mechanical properties for acceptance purposes of chill-cast reference test piece

Alloy	Temper (*see* Note)	Tensile strength N/mm^2	Elongation %
Al–Mg 3	M	150	5
Al–Si 12	M	170	3
Al–Si 10 Mg	M	170	3
Al–Si 10 Mg	TF	240	1,5
Al–Si 7 Mg	TF	250	5

NOTE
M refers to as cast condition.
TF refers to solution heat treated and precipitation hardened condition.

3.6.6 Where the results of a test do not comply with the requirements, the re-test procedure detailed in Ch 2,1.4 is to be applied. Where castings are to be used in the heat treated condition, the re-test sample must have been heat treated together with the castings it represents.

3.7 Visual examination

3.7.1 All castings are to be cleaned and adequately prepared for inspection.

3.7.2 The accuracy and verification of dimensions are the responsibility of the manufacturer, unless otherwise agreed.

3.7.3 Before acceptance, all castings are to be presented to the Surveyor for visual examination.

3.8 Rectification of defective castings

3.8.1 At the discretion of the Surveyor, small surface blemishes may be removed by local grinding.

3.8.2 Where appropriate, repair by welding may be accepted at the discretion of the Surveyor. Such repair is to be made in accordance with an approved procedure.

3.9 Pressure testing

3.9.1 Where required by the relevant Rules, castings are to be pressure tested before final acceptance. Unless otherwise agreed, these tests are to be carried out in the presence and to the satisfaction of the Surveyor.

3.10 Identification

3.10.1 The manufacturer is to adopt a system of identification which will enable all finished castings to be traced to the original cast and the Surveyor is to be given full facilities for tracing the casting when required.

3.10.2 All castings which have been tested and inspected with satisfactory results are to be clearly marked with the following details:
(a) Identification number, cast number or other markings which will enable the full history of the casting to be traced.
(b) LR or Lloyd's Register and the abbreviated name of LR's local office.
(c) Personal stamp of the Surveyor responsible for the inspection.
(d) Test pressure where applicable.
(e) Date of final inspection.

3.10.3 Where small castings are manufactured in large numbers, modified arrangements for identification may be specially agreed with the Surveyor.

3.11 Certification of materials

3.11.1 A LR certificate is to be issued (*see* Ch 1,3.1) giving the following particulars for each casting or batch of castings which have been accepted:
(a) Purchaser's name and order number.
(b) Description of castings and alloy type.
(c) Identification number.
(d) Ingot or cast analysis.
(e) General details of heat treatment, where applicable.
(f) Results of mechanical tests.
(g) Test pressure, where applicable.

■ *Section 4*
Aluminium/steel transition joints

4.1 Scope

4.1.1 Provision is made in this Section for explosion bonded composite aluminium/steel transition joints used for connecting aluminium structures to steel plating.

4.1.2 Each individual application is to be separately approved as required by the relevant Rules dealing with design and construction.

4.2 Manufacture

4.2.1 Transition joints are to be manufactured by an approved producer in accordance with an approved specification which is to include the maximum temperature allowable at the interface during welding.

4.2.2 The aluminium material is to comply with the requirements of Section 1 and the steel is to be of an appropriate grade complying with the requirements of Ch 3,2.

4.2.3 Alternative materials which comply with International, National or proprietary specifications may be accepted provided that they give reasonable equivalence to the requirements of 4.2.2 or are approved for a specific application.

4.2.4 Intermediate layers between the aluminium and steel may be used, in which case the material of any such layer is to be specified by the manufacturer and is to be recorded in the approval certificate. Any such intermediate layer is then to be used in all production transition joints.

4.3 Visual and non-destructive examination

4.3.1 Each composite plate is to be subjected to 100 per cent visual and ultrasonic examination in accordance with a relevant National Standard to determine the extent of any unbonded areas. Unbonded areas are unacceptable and any such area plus 25 mm of surrounding sound material is to be discarded.

4.4 Mechanical tests

4.4.1 Two shear test specimens and two tensile test specimens are to be taken from each end of each composite plate for tests to be made on the bond strength. One shear and one tensile test specimen from each end are to be tested at ambient temperature after heating to the maximum allowable interface temperature, *see* 4.2.1; the other two specimens are to be tested without heat treatment.

4.4.2 Shear tests may be made on a specimen as shown in Fig. 8.4.1 or an appropriate equivalent. Tensile tests may be made across the interface by welding extension pieces to each surface or by the ram method shown in Fig. 8.4.2 or by an appropriate alternative method.

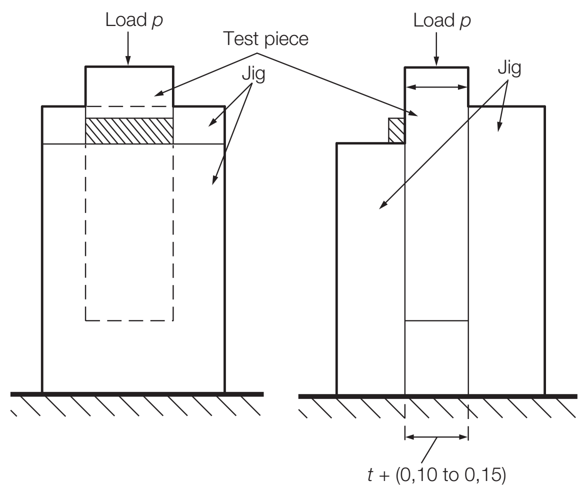


Fig. 8.4.1 Specimen and procedure for shear tests

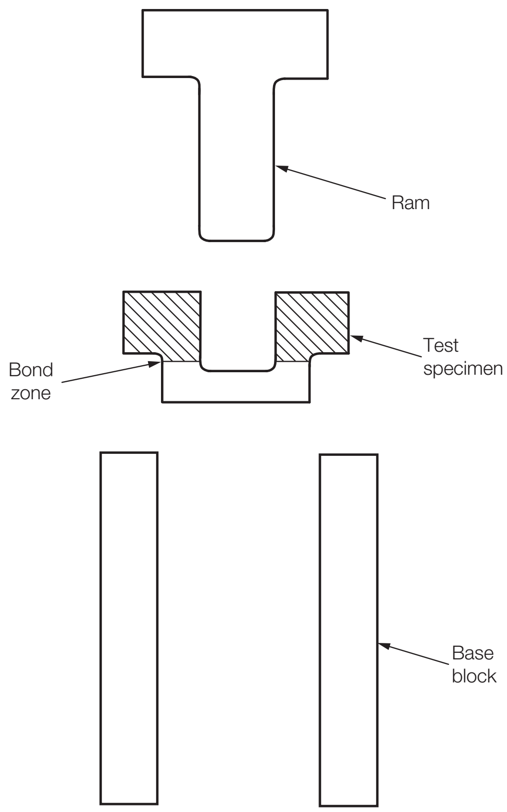


Fig. 8.4.2 Ram tensile test

4.4.3 The shear and tensile strengths of all the test specimens are to comply with the requirements of the manufacturing specification.

4.4.4 If either the shear or tensile strength of the bond is less than the specified minimum but not less than 70 per cent of the specified minimum, two additional shear and two tensile test specimens from each end of the composite plate are to be tested and, in addition, bend tests as described in 4.4.6 and Table 8.4.1 are to be made.

Table 8.4.1 Bend tests on explosion bonded aluminium/steel composites

Type of test	Minimum bend, degrees	Diameter of former
Aluminium in tension	90	3*T*
Steel in tension	90	3*T*
Side bend	90	6*T*
NOTE *T* is the total thickness of the composite plate.		

4.4.5 If either the shear or tensile strength of the bond is less than 70 per cent of the specified minimum the cause is to be investigated. After evaluation of the results of this investigation, LR will consider the extent of composite plate which is to be rejected.

4.4.6 Bend tests, when required, are to be made under the following conditions, as listed in Table 8.4.1:
(a) The aluminium plate is in tension.
(b) The steel plate is in tension.
(c) A side bend is applied.

4.5 Identification

4.5.1 Each acceptable transition strip is to be clearly marked with the following particulars:
(a) LR or Lloyd's Register and the abbreviated name of LR's local office.
(b) Manufacturer's name or trade mark.
(c) Identification mark for the grade of aluminium.
(d) Identification mark for the grade of steel.
The particulars are to be stamped on the aluminium surface at one end of the strip.

4.6 Certification of materials

4.6.1 A manufacturer's certificate validated by LR is to be issued (*see* Ch 1,3.1) and as a minimum is to include the following particulars:
(a) Purchaser's name and order number.
(b) The contract number for which the material is intended, if known.
(c) Address to which the material is dispatched.
(d) Description and dimensions of the material.
(e) Specifications or grades of both the aluminium alloy and the steel and any intermediate layer.
(f) Cast numbers of the steel and aluminium plates.
(g) Identification number of the composite plate.
(h) Mechanical test results (not required on shipping statement).

Section

Section 1 Castings for propellers

1.1 Scope

1.1.1 This Section gives the requirements for copper alloy castings for one-piece propellers and separately cast blades and bosses for fixed pitch and controllable pitch propellers (CPP). These include contra-rotating propellers and propulsors fitted to podded drives and azimuth units.

1.1.2 These castings are to be manufactured and tested in accordance with the appropriate requirements of Chapters 1 and 2 and the specific requirements of this Section.

1.1.3 As an alternative to 1.1.2, castings which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Section or alternatively are approved for a specific application.

1.1.4 The appropriate requirements of this Section may also be applied to the repair and inspection of propellers which have been damaged during service.

1.1.5 Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

1.2 Manufacture

1.2.1 All castings are to be manufactured at foundries approved by Lloyd's Register (hereinafter referred to as 'LR').

1.2.2 The pouring is to be carried out into dried moulds using degassed liquid metal. The pouring is to avoid turbulent flow. Special devices and/or procedures are to be used to prevent slag flowing into the mould.

1.3 Quality of castings

1.3.1 All castings are to be free from surface or internal defects which would be prejudicial to their proper application in service.

1.3.2 The removal and repair of defects are dealt with in 1.9 and 1.10.

1.4 Chemical composition

1.4.1 The chemical compositions of samples from each melt are to comply with the manufacturing specification approved by LR and also with the overall limits given in Table 9.1.1. In addition to carrying out chemical analysis for the elements given in the Table, it is expected that manufacturers will ensure that any harmful residual elements are within acceptable limits.

1.4.2 The use of alloys whose chemical compositions are different from those detailed in Table 9.1.1 will be given special consideration by LR.

1.4.3 The manufacturer is to maintain records of all chemical analyses, which are to be made available to the Surveyor so that he can satisfy himself that the chemical composition of each casting is within the specified limits.

Table 9.1.1 Chemical composition of propeller and propeller blade castings

Alloy designation	Chemical composition of ladle samples %							
	Cu	Sn	Zn	Pb	Ni	Fe	Al	Mn
Grade Cu 1 Manganese bronze (high tensile brass)	52–62	1,5 max.	35–40	0,5 max.	1,0 max.	0,5–2,5	0,5–3,0	0,5–4,0
Grade Cu 2 Ni-manganese bronze (high tensile brass)	50–57	1,5 max.	33–38	0,5 max.	2,5–8,0	0,5–2,5	0,5–2,0	1,0–4,0
Grade Cu 3 Ni-aluminium bronze	77–82	0,1 max.	1,0 max.	0,03 max.	3,0–6,0 (*see* Note)	2,0–6,0 (*see* Note)	7,0–11,0	0,5–4,0
Grade Cu 4 Mn–aluminium bronze	70–80	1,0 max.	6,0 max.	0,05 max.	1,5–3,0	2,0–5,0	6,5–9,0	8,0–20,0

NOTE
For Naval ships, the nickel content is to be higher than the iron content.

1.4.4 When a melt is wholly prepared from ingots for which an analysis is already available, and provided that no significant alloy additions are made during melting, the ingot maker's certified analysis can be accepted subject to occasional checks as required by the Surveyor. If any foundry returns are added to the melts, the ingot manufacturer's chemical analyses are to be supplemented by frequent checks as required by the Surveyor.

1.4.5 For alloys Grade Cu 1 and Cu 2, the zinc equivalent shall not exceed 45 per cent, and is to be calculated using the following formula:

$$\text{zinc equivalent \%} = 100 - \frac{100 \times \%\text{Cu}}{100 + A}$$

where *A* is the algebraic sum of the following:

1 x % Sn
5 x % Al
–0,5 x % Mn
–0,1 x % Fe
–2,3 x % Ni

1.4.6 Samples for metallographic examination are to be prepared from the ends of test bars cast from every melt of Grade Cu 1 and Cu 2 alloys. The proportion of alpha-phase determined from the average of at least five counts is to be not less than 25 per cent.

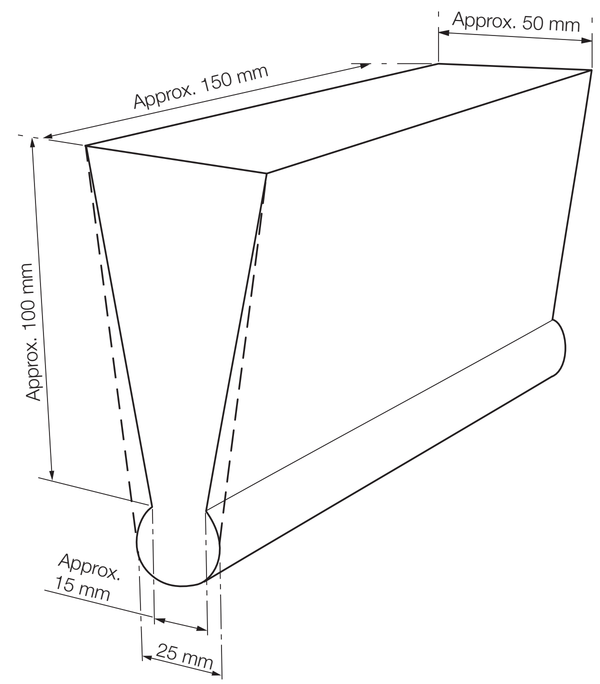


Fig. 9.1.1 Keel block type test sample

1.5 Heat treatment

1.5.1 At the option of the manufacturer, castings may be supplied in the 'as-cast' or heat treated condition. However, if heat treatment is to be applied, full details are to be included in the manufacturing specification.

1.5.2 If any welds are made in the propeller casting, stress relief heat treatment is required in order to minimise the residual stresses. Requirements concerning such heat treatment are given in 1.10.

1.6 Test material

1.6.1 Test samples are to be cast separately from each melt used for the manufacture of propeller or propeller blade castings.

1.6.2 The test samples are to be of the keel block type, generally in accordance with the dimensions given in Fig. 9.1.1 and are to be cast in moulds made from the same type of material as used for the castings.

1.6.3 The method and procedures for the identification of the test specimens, and the castings they represent, are to be agreed with the Surveyor. The identification marks are to be transferred and maintained during the preparation of test specimens.

1.6.4 Where castings are supplied in the heat treated condition, the test samples are to be heat treated together with the castings which they represent.

1.7 Mechanical tests

1.7.1 At least one tensile test specimen representative of each cast is to be prepared. The dimensions of this test specimen are to be in accordance with Fig. 2.2.1 in Chapter 2.

1.7.2 The results of all tensile tests are to comply with the requirements given in Table 9.1.2.

1.7.3 The mechanical properties of alloys whose chemical compositions do not accord with Table 9.1.1 are to comply with a manufacturing specification approved by LR.

Table 9.1.2 Mechanical properties for acceptance purposes: propeller and propeller blade castings

Alloy designation	0,2% proof stress N/mm^2 minimum	Tensile strength N/mm^2 minimum	Elongation on $5,65\sqrt{S_o}$ % minimum
Grade Cu 1 Manganese bronze (high tensile brass)	175	440	20
Grade Cu 2 Ni-manganese bronze (high tensile brass)	175	440	20
Grade Cu 3 Ni-aluminium bronze	245	590	16
Grade Cu 4 Mn-aluminium bronze	275	630	18

1.8 Inspection and non-destructive examination

1.8.1 Propeller castings should be visually inspected at all stages of manufacture. The manufacturer is to draw any significant imperfections to the attention of the Surveyor. Such imperfections are to be verified in accordance with 1.9.

1.8.2 All finished castings are to be subjected to a comprehensive visual examination by the Surveyor, including internal surfaces such as the bore and bolt holes.

1.8.3 For the purpose of these requirements, the blades of propellers, including CPP blades, are divided into three severity Zones A, B and C as shown in Fig. 9.1.2 and detailed in 1.8.4 for blades having skew angles of 25° or less and 1.8.5 for blades having skew angles of greater than 25°.

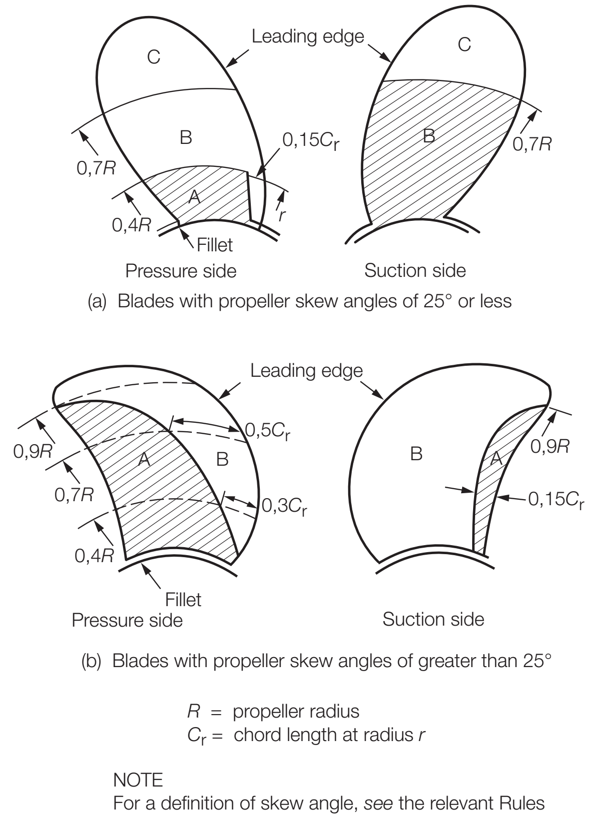


Fig. 9.1.2 Severity zones in all propeller blades

1.8.4 **Skew angles of 25° or less:**

- Zone A is the area on the pressure side of the blade from and including the root fillet to 0,4R and bounded by the trailing edge and by a line at a distance 0,15 times the chord length from the leading edge.
- Zone B includes the areas inside 0,7R on both sides of the blade, excluding Zone A.
- Zone C includes the areas outside 0,7R on both sides of the blade.

1.8.5 **Skew angles of greater than 25°**:

- Zone A is the area on the pressure side of the blade bounded by, and including, the root fillet and a line running from the junction of the leading edge with the root fillet to the trailing edge at 0,9R and passing through the mid-point of the chord at 0,7R and a point situated at 0,3 of the chord length from the leading edge at 0,4R.
- Zone A also includes the area along the trailing edge on the suction side of the blade from the root to 0,9R and with its inner boundary at 0,15 of the chord length tapering to meet the trailing edge at 0,9R.
- Zone B constitutes the whole of the remainder of the blade surfaces.

1.8.6 In propeller blades with continuously loaded tips (CLT), the whole of the tip plate and the adjoining blade to a distance of 100 mm is to be regarded as severity Zone B, *see* Fig. 9.1.3. For propellers with diameters less than 2 m, the width of this zone may be reduced to one tenth of the propeller radius.

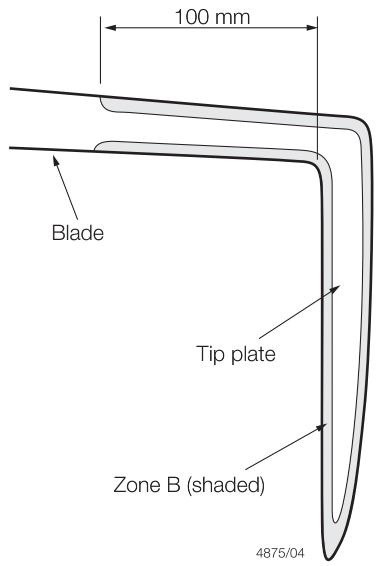
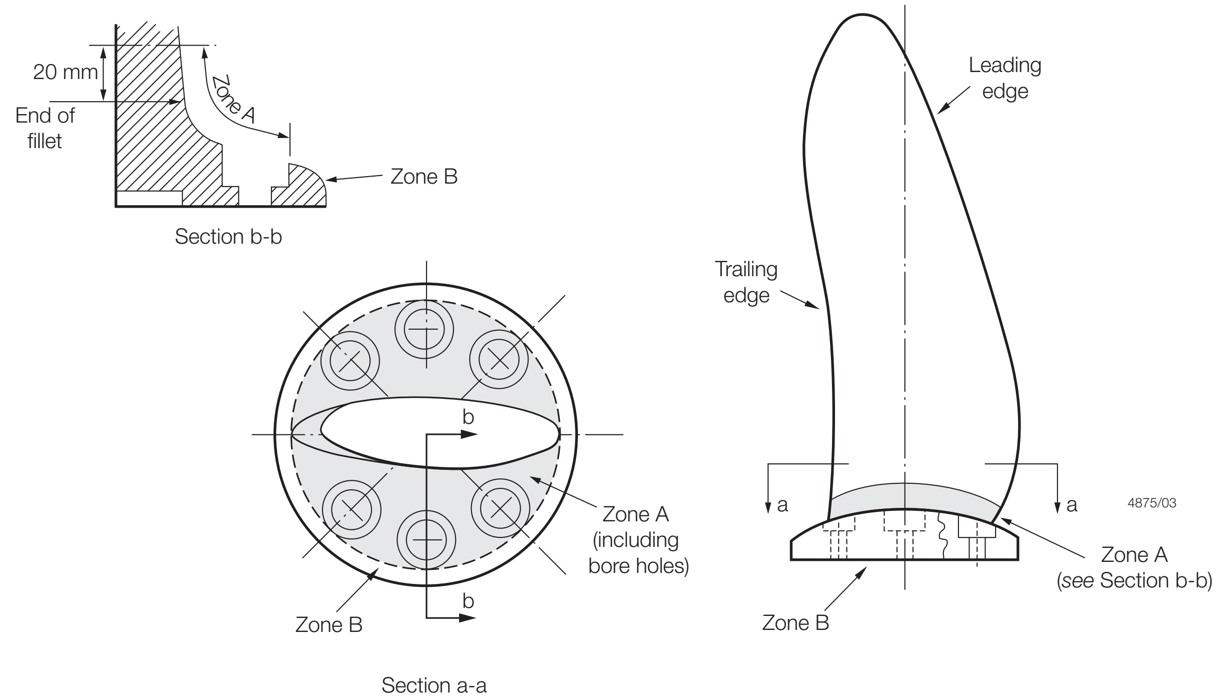


Fig. 9.1.3
Severity Zone B at Continuously loaded blade tip

1.8.7 In addition, the palm of a CPP blade is divided into severity Zones A and B as shown in Fig. 9.1.4.

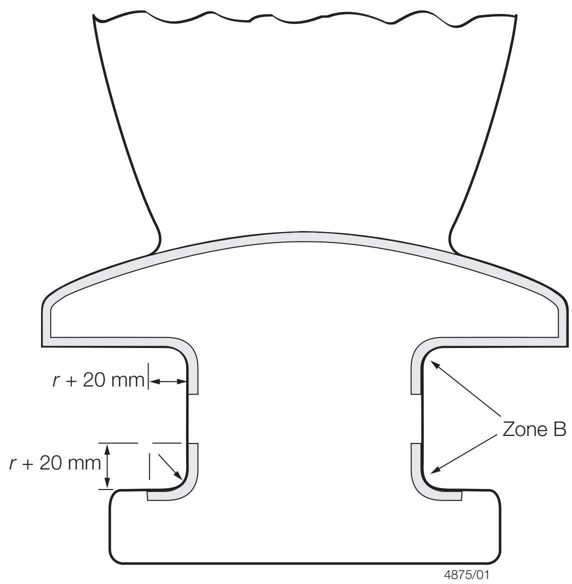
1.8.8 If a CPP blade has an integrally cast journal, the fillets of the journal and the adjoining material up to a distance of 20 mm from the fillet run-outs are to be regarded as Zone B, as indicated in Fig. 9.1.5. The remainder of the surface of the journal may be regarded as Zone C.

1.8.9 Hubs of controllable pitch propellers are to contain a Zone A region at each blade port as shown in Fig. 9.1.6. The remainder may be regarded as Zone C.



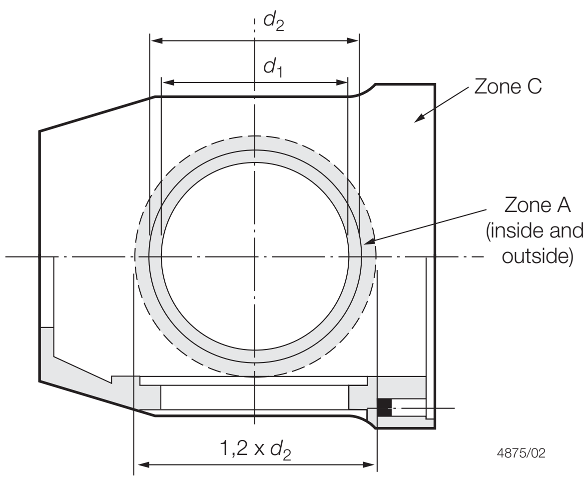
The surfaces of blades are to be divided into severity zones in accordance with Fig. 9.1.2

Fig. 9.1.4 Severity zones for controllable pitch propeller blades



The surfaces of the journal which are not shaded are to be regarded as severity Zone C

Fig. 9.1.5
Severity zones in integrally cast CPP blade journals



(d_1 and d_2 = diameters)

Fig. 9.1.6
Severity zones for controllable pitch propeller hub

1.8.10 On completion of machining and grinding, the whole surface of each casting is to be subjected to a dye penetrant inspection in accordance with a procedure acceptable to LR.

1.8.11 All dye penetrant inspections on Zone A areas in the finished condition are to be made in the presence of the Surveyor.

1.8.12 Dye penetrant inspections on Zones B and C are to be performed by the manufacturer and may be witnessed at the Surveyor's request.

1.8.13 The surface to be inspected shall be divided into reference areas of 100 cm^2. The indications detected shall, with respect to their size and number, not exceed the values given in Table 9.1.3. The area shall be taken in the most unfavourable location relative to the indication being evaluated.

1.8.14 Indications exceeding the acceptance standard in Table 9.1.3 shall be repaired in accordance with 1.9.

1.8.15 All defects requiring repair by welding in new propeller castings are to be recorded on sketches showing their locations and dimensions. Copies of these sketches are to be presented to the Surveyor prior to repair.

1.8.16 Where repairs have been made either by grinding or welding, the repaired areas are to be subjected to dye penetrant inspection in the presence of the Surveyor, regardless of their location.

1.8.17 Where no welds have to be made on a casting, the manufacturer is to provide the Surveyor with a statement that this is the case.

1.8.18 Where it is suspected that a casting contains internal defects, radiographic and/or ultrasonic examination may be required by the Surveyor. The acceptance criteria are to be agreed between the manufacturer and LR in accordance with a recognised standard. The standard ASTM E272-99 (Severity Level 2) or equivalent is to be the radiographic acceptance standard for copper alloy castings. Ultrasonic testing of Cu 1 and Cu 2 is not considered in these Rules. For Cu 3 and Cu 4, ultrasonic inspection of defects may be possible and is to comply with the requirements for steel castings.

1.8.19 The measurement of dimensional accuracy is the responsibility of the manufacturer but the report on dimensional inspection is to be presented to the Surveyor who may require checks to be made and to witness such checks.

1.8.20 Static balancing is to be carried out on all propellers in accordance with the approved plan. Dynamic balancing is necessary for propellers running above 500 rpm.

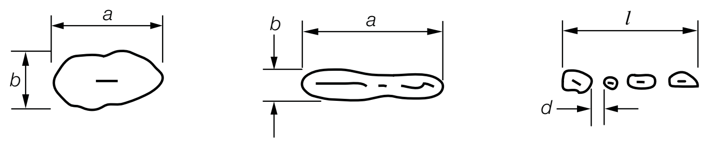
1.9 Rectification of defective castings

1.9.1 The rectification of defective propeller and propeller blade castings is to be carried out in accordance with the requirements given in 1.9.2 to 1.9.12.

Table 9.1.3 Allowable number and size of dye penetrant indications in a reference area of 100 cm^2 (*see* Note 1)

Severity Zones	Max. total number of indications	Type of indications (*see* Note 2)	Max. number of each type (*see* Notes 3 and 4)	Max. acceptable value for 'a' or '*l*' of indications (mm) (*see* Note 2)
A	7	Non-linear Linear Aligned	5 2 2	4 3 3
B	14	Non-linear Linear Aligned	10 4 4	6 6 6
C	20	Non-linear Linear Aligned	14 6 6	8 6 6

NOTES
1. The reference area is defined as an area of 0,1 m^2, which may be square or rectangular, with the major dimension not exceeding 250 mm. The area shall be taken in the most unfavourable location relative to the indication being evaluated.
2. Non-linear, linear and aligned indications are defined as follows:



$\frac{a}{b} < 3$ non-linear $\frac{a}{b} \geq 3$ linear $d \leq 2$ mm aligned

3. Only indications that have any dimension greater than 1,5 mm shall be considered relevant.
4. Single non-linear indications less than 2 mm in Zone A and less than 3 mm in other zones may be disregarded.
5. The total number of non-linear indications may be increased to the maximum total number, or part thereof, represented by the absence of linear or aligned indications.

1.9.2 The rectification of small indications within the acceptance standard of Table 9.1.3 is not generally required except where they occur in closely spaced groups.

1.9.3 Where, in the surface of the end face or bore of a propeller boss, local pores are present which do not themselves adversely affect the strength of the casting, they may be filled with a suitable plastic filler after the appropriate preparation of the defective area. The foundry is to maintain records and details of all castings which have been so rectified.

1.9.4 Where unacceptable defects are found in a casting, they are to be removed by mechanical means, and the surfaces of the resulting depressions are subsequently to be ground smooth. Complete elimination of the defects is to be proved by adequate dye penetrant inspection.

1.9.5 Shallow grooves or depressions resulting from the removal of defects may, at the discretion of the Surveyor, be accepted provided that they will cause no appreciable reduction in the strength of the castings and that they are suitably blended by grinding.

1.9.6 Welded repairs are to be undertaken only when they are considered to be necessary and approved by the Surveyor. In general, welds having an area less than 5 cm^2 are to be avoided.

1.9.7 All weld repairs are to be carried out in accordance with qualified procedures by suitably qualified welders, and are to be completed to the satisfaction of the Surveyor. Records are to be made available to the Surveyor.

1.9.8 Welding is generally not permitted in Zone A and will only be allowed after special consideration.

1.9.9 Prior approval by the Surveyor is required for any welds in Zone B. Complete details of the repair procedure are to be submitted for each case.

1.9.10 Repair by welding is allowed in Zone C provided that there is compliance with 1.9.6 and 1.9.7.

1.9.11 The maximum area of any single repair and the maximum total area of repair in any one zone or region are given in Table 9.1.4.

1.9.12 Where it is proposed to exceed the areas given in Table 9.1.4, the nature and extent of the repair work are to be approved by the Surveyor before commencement of the repair.

1.10 Weld repair procedure

1.10.1 Welding is to be carried out under cover in positions free from draughts and adverse weather conditions.

1.10.2 The manufacturer is to submit a detailed welding procedure specification covering the weld preparation, welding parameters, filler metal, preheating, post-weld heat treatment and inspection procedures.

Table 9.1.4 Permissible rectification of new propellers by welding

<table>
<tr><th>Severity zone or region</th><th>Maximum individual area of repair</th><th>Maximum total area of repairs</th></tr>
<tr><td>Zone A</td><td colspan="2">Weld repairs not generally permitted</td></tr>
<tr><td>Zone B</td><td rowspan="2">60 cm^2 or 0,6% x S whichever is the greater</td><td rowspan="2">200 cm^2 or 2% x S, whichever is the greater in combined Zones B and C but not more than 100 cm^2 or 0,8% x S, whichever is the greater, in Zone B on the pressure side</td></tr>
<tr><td>Zone C</td></tr>
<tr><td>Other regions (see Note)</td><td>17 cm^2 or 1,5% area of the region whichever is the greater</td><td>50 cm^2 or 5% x area of the region whichever is the greater</td></tr>
<tr><td colspan="3">where S = area of one side of a blade = $0,79 \dfrac{D^2 B}{N}$
D = finished diameter of propeller
B = developed area ratio
N = number of blades</td></tr>
<tr><td colspan="3">NOTE
Other regions include:
(a) the bore;
(b) the forward and aft faces of the boss;
(c) the outer surface of the boss to the start of the blade root fillets;
(d) the inner face of a CPP blade palm;
(e) all surfaces of CPP nose cones;
(f) the surfaces of integral journals to CPP blades other than the fillets.</td></tr>
</table>

1.10.3 Before welding is started, Welding Procedure Qualification tests are to be carried out and witnessed by the Surveyor. Each welder is to be qualified to carry out the proposed welding using the same process, consumable and position which are to be used for the repair.

1.10.4 Defects to be repaired by welding are to be removed completely by mechanical means (e.g. grinding, chipping or milling). Removal of defects in accordance with the requirements for Zone A is to be demonstrated by dye penetrant inspection in the presence of the Surveyor. The excavation is to be prepared in a manner which will allow good fusion and is to be clean and dry.

1.10.5 Metal arc welding with the electrodes or filler wire used in the procedure tests is to be used for all types of repairs. Welds should preferably be made in the downhand (flat) position. Where necessary, suitable preheat is to be applied before welding, and the preheat temperature is to be maintained until welding is completed.

1.10.6 When flux coated electrodes are used they are to be dried immediately before use, in accordance with the manufacturer's instructions.

1.10.7 All slag, undercuts and other defects are to be removed before the subsequent run is deposited.

1.10.8 With the exception given in 1.10.9, all weld repairs in areas of solid propellers exposed to sea-water, and all repairs to separately cast blades, are to be stress relief heat treated.

1.10.9 Stress relief heat treatment is not mandatory after welding Grade Cu 3 castings in Zone C unless a welding consumable susceptible to stress corrosion (e.g. complying with the composition range of Grade Cu 4) is used. All welds in Zones A and B however, must be stress relieved by heat treatment, regardless of alloy.

1.10.10 Propeller and propeller blades are to be stress relieved within the following temperature ranges:

alloy Grades Cu 1 and Cu 2	350°C to 550°C
alloy Grade Cu 3	450°C to 500°C
alloy Grade Cu 4	450°C to 600°C

Soaking times are to be in accordance with Table 9.1.5, and subsequent cooling from the soaking temperature is to be suitably controlled to minimise residual stresses and is not to exceed 50°C per hour until the temperature is below 200°C. Care should be taken to avoid heating castings in the Grade Cu 3 alloy at temperatures between 300° and 400°C for prolonged periods.

Table 9.1.5 Soaking times for stress relief heat treatment of copper alloy propellers

Stress relief temperature °C (*see* Notes)	Alloy Grade Cu1 and Cu2		Alloy Grade Cu3 and Cu4	
	Hours per 25 mm of thickness	Maximum recommended total time hours	Hours per 25 mm of thickness	Maximum recommended total time hours
350	5	15	—	—
400	1	5	—	—
450	1/2	2	5	15
500	1/4	1	1	5
550	1/4	1/2	1/2	2
600	—	—	1/4	1

NOTES
1. Treatment at 550°C is not applicable to alloy Grade Cu3.
2. Treatment at 600°C is only applicable to alloy Grade Cu4.

1.10.11 Stress relief heat treatment is to be carried out, where possible, in furnaces having suitable atmosphere and temperature control. Sufficient thermocouples are to be attached to the casting to measure the temperature at positions of extremes of thickness.

1.10.12 As an alternative to 1.10.11, local stress relief heat treatment may be accepted, provided that the Surveyor is satisfied that the technique will be effective and that adequate precautions are taken to prevent the introduction of detrimental temperature gradients. Where local stress relief heat treatment is approved, adequate temperature control is to be provided. The area of the propeller or blade adjacent to the repair is to be suitably monitored and insulated to ensure that the required temperature is maintained and that temperature gradients are moderate. Care should be taken to select the shape of an area to be heat treated which will minimise residual stresses.

1.10.13 On completion, welds are to be ground smooth for visual examination and dye penetrant inspection. Where a propeller or propeller blade is to be stress relief heat treated, a visual examination is to be made before heat treatment, and both visual and dye penetrant examinations are to be made after the stress relief heat treatment. Irrespective of location, all weld repairs are to be assessed according to Zone A in Table 9.1.3.

1.10.14 The foundry is to maintain full records detailing the weld procedure, heat treatment and extent and location on drawings of repairs made to each casting. These records are to be available for review by the Surveyor, and copies of individual records are to be supplied to the Surveyor on request.

1.10.15 LR reserves the right to restrict the amount of repair work accepted from a manufacturer when it appears that repetitive defects are the result of improper foundry techniques or practices.

1.11 Identification

1.11.1 Castings are to be clearly marked by the manufacturer in accordance with the requirements of Chapter 1. The following details are to be shown on all castings which have been accepted:
- (a) Identification mark which will enable the full history of the item to be traced.
- (b) Alloy grade.
- (c) LR or Lloyd's Register and the abbreviated name of LR local office.
- (d) Personal stamp of Surveyor responsible for the final inspection.
- (e) Date of final inspection.
- (f) Skew angle, if in excess of 25°. *See* Pt 5, Ch 7,1 of the Rules for Ships for the definition of skew angle.

1.12 Certification of materials

1.12.1 A LR certificate is to be issued for each propeller, *see* Ch 1,3.1.

1.12.2 The manufacturer is to provide the Surveyor with the following particulars for each casting:
- (a) Purchaser's name and order number.
- (b) Description of casting.
- (c) Alloy designation and/or trade name.
- (d) Identification number of casting.
- (e) Cast identification number if different from (d).
- (f) Details of heat treatment, where applicable.
- (g) Skew angle, if in excess of 25°. *See* the relevant Rules for the definition of skew angle.
- (h) Final weight of casting.
- (j) Results of non-destructive tests and details of test procedures.
- (k) Proportion of alpha-structure for Cu1 and Cu2 alloys.
- (l) Results of mechanical tests.
- (m) A sketch showing the location and extent of welding repairs (if any).

Section 2 Castings for valves, liners and bushes

2.1 Scope

2.1.1 This Section makes provision for copper alloy castings for valves, liners, bushes and other fittings intended for use in the construction of ships, other marine structures, machinery and pressure piping systems.

2.1.2 Castings are to be manufactured and tested in accordance with Chapters 1 and 2, and also with the requirements given in this Section.

2.1.3 As an alternative to 2.1.2, castings which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Section or alternatively are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

2.2 Manufacture

2.2.1 Castings are to be manufactured at foundries approved by LR.

2.3 Quality of castings

2.3.1 All castings are to be free from surface or internal defects which would be prejudicial to their proper application in service.

2.4 Chemical composition

2.4.1 The chemical composition is to comply with the requirements of a National or International Standard and, where appropriate, with the limits for the principal elements of the preferred alloys listed in Tables 9.2.1 and 9.2.2.

2.4.2 With the exception given in 2.4.3, chemical analysis is required on each cast.

2.4.3 Where a cast is wholly prepared from ingots for which an analysis is already available, and provided that no significant alloy additions are made during melting, the ingot maker's certified analysis can be accepted subject to occasional check tests as requested by the Surveyor. The frequency of these check tests should, as a minimum, be one in every ten casts. If one of these check analyses fails to comply with the specification, checks are to be made on the previous and subsequent melts. If one or both of these further analyses is unsatisfactory, chemical analysis is to be carried out on all further melts until the Surveyor is satisfied that a return can be made to the use of occasional check tests.

2.5 Heat treatment

2.5.1 Where required by the specification, castings may be supplied in either the 'as-cast' or heat treated condition.

2.5.2 Where castings are supplied in a heat treated condition, the test samples are to be heat treated with the castings they represent prior to the preparation of the tensile test specimens.

2.6 Test material

2.6.1 Test material sufficient for the tests specified in 2.6.4 and for possible re-test purposes is to be provided for each cast of material.

2.6.2 The test material is to be separately cast into moulds made of the same material as that used for the castings they represent.

2.6.3 For the alloys listed in Table 9.2.1, sand cast test bars are generally to be in accordance with Fig. 9.2.1.

2.6.4 For the alloys listed in Table 9.2.2, keel block type test samples are to be in accordance with Fig. 9.1.1.

Table 9.2.1 Chemical compositions of long freezing range alloys: principal elements only

Alloy type	Designation	Chemical composition						Typical applications
		Cu	Sn	Zn	Pb	Ni	P	
Phosphor bronze	Cu Sn11P Cu Sn12	87,0 – 89,5 85,0 – 88,5	10,0 – 11,5 11,0 – 13,0	0,05 max. 0,50 max.	0,25 max. 0,7 max.	0,10 max. 2,0 max.	0,5 – 1,0 0,60 max.	Liners, bushes, valves and fittings
Gunmetal	Cu Sn10 Zn2	Remainder	9,5 – 10,5	1,75 – 2,75	1,5 max.	1,0 max.	—	Liners, valves and fittings
Leaded gunmetal	Cu Sn5 Zn5 Pb5 Cu Sn7 Zn2 Pb3 Cu Sn7 Zn4 Pb7 Cu Sn6 Zn4 Pb2	83,0 – 87,0 85,0 – 89,0 81,0 – 85,0 86,0 – 90,0	4,0 – 6,0 6,0 – 8,0 6,0 – 8,0 5,5 – 6,5	4,0 – 6,0 1,5 – 3,0 2,0 – 5,0 3,0 – 5,0	4,0 – 6,0 2,5 – 3,5 5,0 – 8,0 1,0 – 2,0	2,0 max. 2,0 max. 2,0 max. 1,0 max.	0,10 max. 0,10 max. 0,10 max. 0,05 max.	Bushes, valves and fittings
Leaded bronze	Cu Sn10 Pb10 Cu Sn5 Pb9 Cu Sn7 Pb15 Cu Sn5 Pb20	78,0 – 82,0 80,0 – 87,0 74,0 – 80,0 70,0 – 78,0	9,0 – 11,0 4,0 – 6,0 6,0 – 8,0 4,0– 6,0	2,0 max. 2,0 max. 2,0 max. 2,0 max.	8,0 – 11,0 8,0 – 10,0 13,0 – 17,0 18,0 – 23,0	2,0 max. 2,0 max. 0,5 – 2,0 0,5 – 2,5	0,10 max. 0,10 max. 0,10 max. 0,10 max.	Bushes

Table 9.2.2 Chemical compositions of short freezing range alloys: principal elements only

Alloy type	Designation	Chemical composition								Typical applications
		Cu	Ni	Fe	Mn	Cr	Nb	Si	Al	
Copper 30% nickel	Cu Ni30 Fe1 Mn1 Cu Ni30 Fe1 Mn1 Nb Si Cu Ni30 Cr2 Fe Mn Si (*see* Note 1)	64,5 min. Remainder Remainder	29,0–31,0 29,0–31,0 29,0–32,0	0,5–1,5 0,5–1,5 0,5–1,0	0,6–1,2 0,6–1,2 0,5–1,0	– – 1,5–2,0	– 0,5–1,0 –	0,1 max. 0,3–0,7 0,15–0,50	– – –	Flanges, valves and fittings
Copper 10% nickel	Cu Ni10 Fe1 Mn1	84,5 min.	9,0–11,0	1,0–1,8	1,0–1,5	–	1,0 max.	0,10 max.	–	Flanges, valves and fittings
Aluminium bronze	Cu Al10 Fe5 Ni5 Cu Al11 Fe6 Ni6	76,0–83,0 72,0–78,0	4,0–6,0 (*see* Note 2) 4,0–7,5 (*see* Note 2)	4,0–5,5 (*see* Note 2) 4,0–7,0 (*see* Note 2)	3,0 max. 2,5 max.	– –	– –	0,1 max. 0,1 max.	8,5–10,5 10,0–12,0	Bushes, valves and fittings

NOTES
1. Normally alloy Cu Ni30 Cr2 Fe Mn Si contains 0,1 to 0,25% titanium and 0,05 to 0,15% zirconium.
2. For Naval ships, the nickel content is to be higher than the iron content.

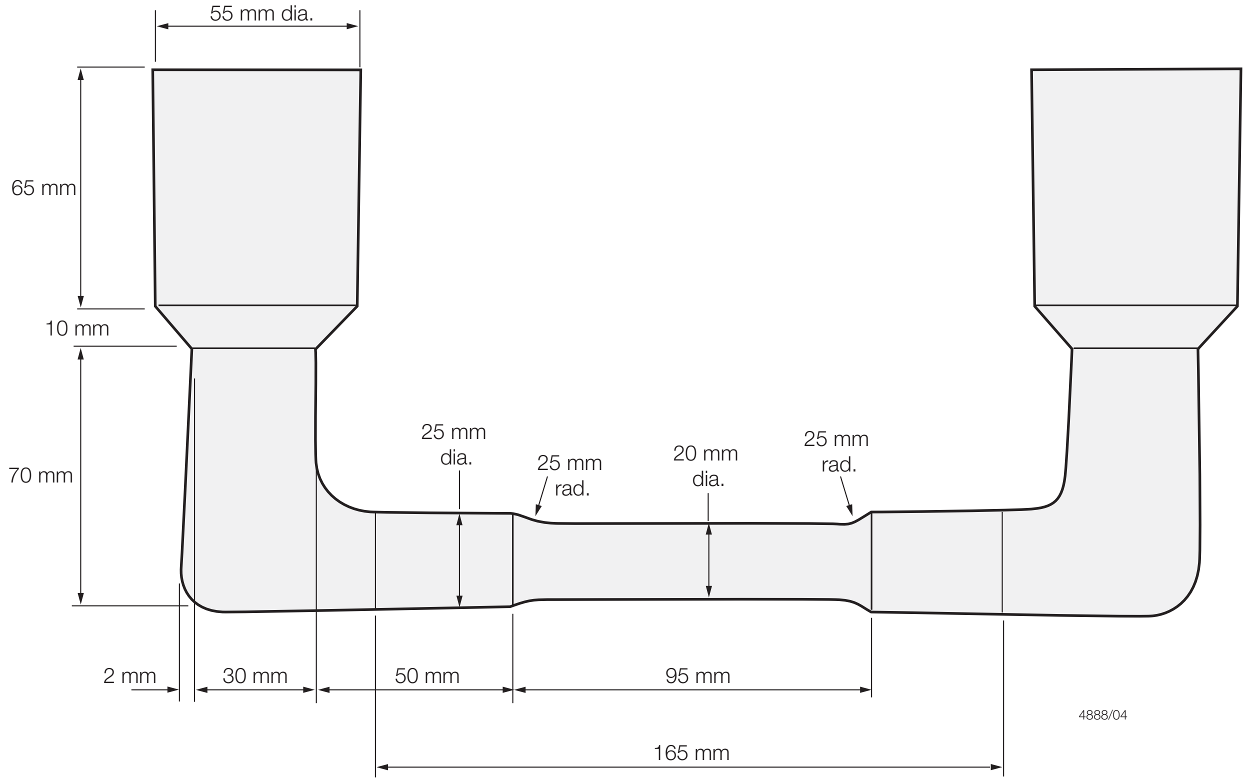


Fig. 9.2.1 Sand cast test bars for long freezing range alloys

2.6.5 If it is proposed to use any other form of test bar, this is to be agreed in advance with the Surveyor.

2.6.6 As an alternative, for liners and bushes, the test material may be taken from the ends of the castings.

2.7 Mechanical tests

2.7.1 A tensile test specimen is to be prepared from each test sample. The dimensions of the specimens are to comply with Fig. 2.2.1 or Fig. 2.2.2 in Chapter 2.

2.7.2 The results of all tests are to comply with the appropriate requirements given in Tables 9.2.3 and 9.2.4.

Table 9.2.3 Mechanical properties of long freezing range alloys for acceptance purposes

Alloy type	Designation	0,2% proof stress N/mm^2 minimum (*See* Note 1)		Tensile strength N/mm^2 minimum		Elongation on $5{,}65\sqrt{S_o}$ % minimum	
		Sand	Centrifugal	Sand	Centrifugal	Sand	Centrifugal
Phosphor bronze	Cu Sn11 P Cu Sn12	130 140	170 150	250 260	330 280	5 7	4 5
Gunmetal	Cu Sn10 Zn2	130	130	270	250	13	5
Leaded gunmetal	Cu Sn5 Zn5 Pb5 Cu Sn7 Zn2 Pb3 Cu Sn7 Zn4 Pb7 Cu Sn6 Zn4 Pb2	90 130 120 110	110 130 120 110	200 230 230 220	250 260 260 240	13 14 15 15	13 12 12 12
Leaded bronze	Cu Sn10 Pb10 Cu Sn5 Pb9 Cu Sn7 Pb15 Cu Sn5 Pb20	80 60 80 70	110 90 90 80	180 160 170 150	220 200 200 170	8 7 8 5	6 6 7 6

NOTES
1. The 0,2% proof stress values are given for information purposes only and, unless otherwise agreed, are not required to be verified by test.
2. Castings may be supplied in the chill cast condition in which case the mechanical properties requirements are to be in accordance with a specification agreed by LR.

Table 9.2.4 Mechanical properties of short freezing range alloys for acceptance purposes

Alloy type	Designation	0,2% proof stress N/mm^2 minimum (*See* Note 1)		Tensile strength N/mm^2 minimum		Elongation on $5{,}65\sqrt{S_o}$ % minimum	
		Sand	Centrifugal	Sand	Centrifugal	Sand	Centrifugal
Copper 30% Nickel	Cu Ni30 Fe1 Mn1 Cu Ni30 Fe1 Mn1 Nb Si Cu Ni30 Cr2 Fe Mn Si	120 230 250	120 — —	340 440 440	340 — —	18 18 18	18 — —
Copper 10% Nickel	Cu Ni10 Fe1 Mn1	120	100	280	280	20	25
Aluminium Bronze	Cu Al10 Fe5 Ni5 Cu Al11 Fe6 Ni6	250 320	280 380	600 680	650 750	13 5	13 5

2.8 Inspection

2.8.1 All castings are to be cleaned and adequately prepared for inspection. Before acceptance, all castings are to be presented to the Surveyor for visual examination. This is to include the examination of internal surfaces, where applicable.

2.8.2 For valves and other pressure components, dye penetrant inspection is required and the Surveyor is to witness the tests. Unless otherwise agreed, the acceptance criteria to be applied are to meet the requirements of Table 9.2.5, or equivalent.

2.8.3 The accuracy and verification of dimensions are the responsibility of the manufacturer. However, the report on dimensional inspection is to be presented to the Surveyor who may request to witness confirmatory measurements.

Table 9.2.5 Visual and surface NDE acceptance criteria for valves and pressure components

Defect type	Acceptance criteria for visual and surface NDE, *see* Note
Linear indications	Not permitted
Porosity	Individual pores are not to exceed 3 mm diameter bleed out, and the sum of the diameters of all indications in an area of 70 x 70 mm is not to exceed 24 mm^2

NOTE
Inspection is to be in accordance with a procedure acceptable to LR.

2.9 Rectification of defective castings

2.9.1 Subject to the prior approval of the Surveyor, castings containing local porosity may be rectified by impregnation with a suitable plastic filler provided that the extent of the porosity is such that it does not adversely affect the strength of the casting.

2.9.2 Proposals to repair a defective casting by welding are to be submitted to the Surveyor before this work is commenced. The Surveyor is to be satisfied that the number, position and size of the defects are such that the castings can be efficiently repaired.

2.9.3 Where approval is given for the repair by welding, complete elimination of the defects is to be proven by adequate non-destructive testing.

2.9.4 All welding is to be in accordance with an approved and qualified weld procedure and carried out by a qualified welder.

2.9.5 A statement and/or sketch detailing the extent and position of all weld repairs is to be prepared by the manufacturer as a permanent record. These records are to be available for review by the Surveyor, and copies of individual records are to be supplied to the Surveyor on request.

2.9.6 The alloys listed in Table 9.2.1 are not satisfactory for repair by welding which is generally not permitted. Weld repairs may, however, be considered in special circumstances provided that a suitable procedure, with proof of previous satisfactory repairs is submitted to the Surveyor.

2.9.7 The welding during manufacture of liners is not permitted in any alloy containing more than 0,5 per cent lead.

2.10 Pressure testing

2.10.1 Where required by the relevant Rules, castings are to be pressure tested before final acceptance. Unless otherwise agreed, these tests are to be carried out in the presence of the Surveyors and are to be to their satisfaction.

2.11 Identification

2.11.1 The manufacturer is to adopt a system of identification which will enable all finished castings to be traced to the original cast, and the Surveyor is to be given full facilities for tracing the casting when required.

2.11.2 Before acceptance, all castings which have been tested and inspected with satisfactory results are to be clearly marked by the manufacturer with the following details:

(a) Identification number, cast number or other markings which will enable the full history of the casting to be traced.
(b) LR or Lloyd's Register and the abbreviated name of LR's local office.
(c) Personal stamp of the Surveyor responsible for inspection.
(d) Test pressure, where applicable.
(e) Date of final inspection.

2.11.3 Where small castings are manufactured in large numbers, modified arrangements for identification may be specially agreed with the Surveyor.

2.12 Certification of materials

2.12.1 A LR certificate is to be issued, *see* Ch 1,3.1.

2.12.2 The manufacturer is to provide the Surveyor with the following particulars for each casting or batch of castings which has been accepted:

(a) Purchaser's name and order number.
(b) Description of castings and alloy grade.
(c) Identification number.
(d) Ingot or cast analysis.
(e) Full details of heat treatment, where applicable.
(f) Mechanical test results.
(g) Test pressure, where applicable.

2.12.3 In addition to 2.12.2, the manufacturer is to provide, where applicable, a statement and/or sketch detailing the extent and position of all weld repairs made to each casting.

■ *Section 3* Tubes

3.1 Scope

3.1.1 Provision is made in this Section for seamless copper and copper alloy tubes intended for use in condensers, heat exchangers and pressure piping systems.

3.1.2 Tubes for Class I and II pressure systems (as defined in the relevant Rules) are to be manufactured and tested in accordance with the requirements of Chapters 1 and 2 and the requirements of this Section.

3.1.3 As an alternative to 3.1.2, tubes which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Section or alternatively are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

3.1.4 Tubes for Class III pressure systems are to be manufactured and tested in accordance with the requirements of a National or International Standard recognised by LR. The manufacturer's test certificate will be acceptable and is to be provided for each batch of material.

3.2 Manufacture

3.2.1 Tubes for Class I and II pressure systems are to be manufactured at a works approved by LR for the grade of material being supplied.

3.2.2 Tubes for Class III pressure systems are not required to be manufactured at a works approved by LR.

3.3 Quality

3.3.1 Tubes are to be clean and free from surface and internal defects and residues from manufacturing operations.

3.3.2 The tubes are to be supplied in smooth, round, straight lengths and the manufacturer is to guarantee freedom from deleterious films in the bore. The ends are to be cut clean and square with the axis of the tube and are to be de-burred.

3.4 Dimensional tolerances

3.4.1 The tolerances on the wall thickness and diameter of the tubes are to be in accordance with a National or International Standard recognised by LR.

3.4.2 The measurement of dimensional accuracy and compliance with the specification are the responsibility of the manufacturer, but the reports are to be made available to the LR Surveyors, who may require checks to be made in their presence.

3.5 Chemical composition

3.5.1 The chemical composition is to comply with the requirements of a National or International Standard recognised by LR and comply with the base limits for the principal elements given in Table 9.3.1.

3.6 Heat treatment

3.6.1 Copper-phosphorus and aluminium brass tubes are to be supplied in the annealed condition. Aluminium brass tubes may additionally be required to be given a suitable stress relieving heat treatment when subjected to a cold straightening operation after annealing.

3.6.2 Tubes in the copper-nickel iron alloys are to be supplied in a solution heat treated condition to ensure that no iron rich phases are present.

3.7 Mechanical tests

3.7.1 Tubes are to be presented for test in batches of 300 lengths. A batch is to consist of tubes of the same size, manufactured from the same material grade.

3.7.2 At least one length is to be selected at random from each batch and subjected to the following tests:
(a) Tensile test.
(b) Flattening test.
(c) Drift expanding test.

3.7.3 The procedures for mechanical tests and the dimensions of the test specimens are to be in accordance with Chapter 2.

3.7.4 The flattening test is to be continued until the interior surfaces of the tube meet.

3.7.5 For the drift expanding test, the mandrel is to have an included angle of 45°.

3.7.6 The results of all mechanical tests are to comply with the appropriate requirements given in Table 9.3.2.

3.7.7 At the discretion of the Surveyor, a modified testing procedure may be adopted for small quantities of materials. In such cases, these may be accepted on the manufacturer's declared chemical composition and hardness tests or other evidence of satisfactory properties.

Table 9.3.1 Chemical composition of principal elements only

Designation	Chemical composition %								
	Cu	As	P	Fe	Pb	Ni	Al	Mn	Zn
Copper-phosphorus deoxidised–non-arsenical	99,85 min.	–	0,013–0,050	—	—	—	—	—	—
Copper-phosphorus deoxidised–arsenical	99,2 min.	0,30–0,50	0,013–0,050		—	—	—	—	—
Aluminium brass	76,0–79,0	0,02–0,06	—	0,06 max.	0,07 max.	—	1,8–2,5	—	Remainder
90/10 Copper-nickel-iron (*see* Note)	Remainder	—	—	1,0-2,0	—	9,0–11,0	—	0,5–1,0	—
70/30 Copper-nickel-iron (*see* Note)	Remainder	—	—	0,40–1,00	—	29,0–33,0	—	0,5–1,5	—

NOTE
Where the purchaser specifies that the product is intended for subsequent welding applications, the following limits will apply:

Zn	0,50% max.	S	0,02% max.
Pb	0,02% max.	C	0,05% max.
P	0,02% max.		

Table 9.3.2 Mechanical properties for acceptance purposes

Designation	0,2% proof stress N/mm^2 minimum	Tensile strength N/mm^2 minimum	Elongation on $5,65\sqrt{S_o}$ % minimum	Drift expansion test % minimum	Grain size mm maximum (*see* Note)
Copper-phosphorus deoxidised–non-arsenical	65	220	40	40	—
Copper-phosphorus deoxidised–arsenical	65	220	40	40	—
Aluminium brass	125	320	40	30	0,045
90/10 Copper-nickel-iron	100	270	30	30	0,045
70/30 Copper-nickel-iron	120	360	30	30	0,045

NOTE
When a maximum grain size is specified, the structure is to be completely re-crystallised. The manufacturer is to guarantee the grain size, but testing of each batch will not be required.

3.8 Visual examination

3.8.1 All tubes are to be visually examined. The manufacturer is to provide adequate lighting conditions to enable an internal and external examination of the tubes to be carried out.

3.8.2 The inner and outer surfaces are to be clean and smooth but may have a superficial, dull iridescent film on both the inner and outer surfaces.

3.9 Hydraulic test

3.9.1 Each tube is to be subjected to a hydraulic test at the manufacturer's works.

3.9.2 The hydraulic test pressure is to be determined from the following formula, except that the maximum test pressure need not exceed 70 bar:

$$P = \frac{20st}{D}$$

where

P = test pressure, in bar
D = nominal outside diameter, in mm
t = nominal wall thickness, in mm
s = 40 for copper-phosphorus
60 for Al-brass and
90/10 copper nickel iron
75 for 70/30 copper nickel iron.

3.9.3 The test pressure is to be maintained for sufficient time to permit proof that the tubes do not weep, leak or undergo a permanent increase in diameter. Unless otherwise agreed, the manufacturer's certificate of satisfactory hydraulic test will be accepted.

3.9.4 Where it is proposed to adopt a test pressure other than that determined in 3.10.2, the proposal will be subject to special consideration.

3.9.5 Subject to special approval, an automated eddy current test can be accepted in lieu of the hydraulic test. Discontinuous irregularities on the external and internal surfaces of the tubes are permitted if they are within the agreed dimensional tolerances, with the exception of cracks, which are not permitted.

3.10 Rectification of defects

3.10.1 The repair of defects by welding is not permitted.

3.11 Identification

3.11.1 Tubes are to be clearly marked by the manufacturer in accordance with the requirements of Chapter 1. The following details are to be shown on all materials which have been accepted:

(a) LR or Lloyd's Register.
(b) Manufacturer's name or trade mark.
(c) Grade of material or designation code.
(d) Identification number and/or initials which will enable the full history of the item to be traced.

3.11.2 Identification is to be by rubber stamp or stencils. Hard stamping is not permitted.

3.12 Certification of materials

3.12.1 A manufacturer's certificate validated by LR is to be issued (*see* Ch 1,3.1), giving the following particulars for each casting or batch of castings which has been accepted:

(a) Purchaser's name and order number.
(b) Specification or grade of material.
(c) Description and dimensions.
(d) Cast number and chemical composition.
(e) Mechanical test results.
(f) Results of stress corrosion cracking test, where applicable.
(g) Hydraulic test report.

Equipment for Mooring and Anchoring

Section

Section 1 Anchors

1.1 Scope

1.1.1 This Section makes provision for the manufacture and testing of anchors constructed from cast, forged and fabricated components.

1.1.2 This Section is applicable to the following types of anchor:

(a) Ordinary.
(b) High holding power (HHP).
(c) Super high holding power (SHHP).

1.1.3 In the context of this Section, the reference to swivels refers to those directly attached to the anchor shank in lieu of the conventional 'D' shackle. For other mooring equipment swivels, *see* 2.13.

1.2 Manufacture

1.2.1 All anchors are to be of an approved design.

1.3 Cast steel anchors

1.3.1 Cast steel anchor heads, shanks, shackles and swivels are to be manufactured and tested in accordance with the requirements of Ch 4,1 and Ch 4,2. The Special grade quality is to be used for anchor heads, shanks and shackles.

1.3.2 Special consideration will be given to the use of other grades of steel for the manufacture of swivels.

1.3.3 To confirm the quality of cast anchor components, the Surveyor is to witness drop and hammering tests.

1.3.4 When drop and hammering tests are required, they are to be carried out as follows:

(a) Each anchor, or the components of an anchor made from more than one piece, is to be dropped from a clear height of 4 m onto a steel slab laid on a solid foundation.
(b) Separately cast flukes, shanks and shackles are to be suspended horizontally from a clear height of 4 m before being dropped.
(c) Anchors cast in one piece are to be drop tested twice from a clear height of 4 m. For the first test, the shank and flukes are to be horizontal. For the second test, two steel blocks are to be placed on the slab, arranged so that the middle of each fluke makes contact with the blocks without the crown making contact with the slab, and the orientation of the anchor is to be vertical with the crown nearest the slab.
(d) If the slab is broken by the impact, the test is to be repeated on a new slab.

1.3.5 When hammering tests are required, they are to be carried out after the drop test on each anchor head and shank, which is slung clear of the ground, using a non-metallic sling, and hammered to check the soundness of the component. A hammer of at least 3 kg mass is to be used.

1.3.6 As part of the manufacturer's works approval, consideration may be given to carrying out drop tests in alternative locations to the manufacturer's when the facilities and location are not suitable.

1.3.7 Repair of fractures or unsoundness detected during the drop or hammering tests are not permitted and the component is to be rejected.

1.4 Forged steel anchors

1.4.1 Forged steel anchor pins, swivels, shanks and shackles are to be manufactured and tested in accordance with the requirements of Ch 5,1 and Ch 5,2 carbon and carbon-manganese steel for welded construction. Rolled steel bar may be used provided that the requirements of Ch 5,1.2.9 are met.

1.4.2 Special consideration will be given to other grades of steel for the manufacture of swivels.

1.5 Fabricated steel anchors

1.5.1 Where it is proposed to use plate material for fabricated steel anchors, it is to comply with the requirements of Ch 3,2 or Ch 3,3, and the proposed manufacturing procedure is to be submitted for approval.

1.5.2 Fabricated anchors are to be manufactured in accordance with Chapter 13.

1.5.3 Stress relief is to be carried out as required in the approved welding procedure.

1.6 Rectification

1.6.1 All rectification is to be agreed with the Surveyor.

1.6.2 Rectification of defective castings is to be carried out in accordance with Ch 4,1.9.

1.6.3 Rectification of defective forgings is to be carried out in accordance with Ch 5,1.9.

1.6.4 Rectification of defective fabricated anchors is to be carried out by suitably qualified welders within the parameters of the approved welding procedure used in construction.

1.6.5 Rectification of defective castings, forgings or fabricated anchors by welding is to be carried out using qualified weld procedures in accordance with Ch 12,1 and Ch 12,2, and in accordance with Ch 13,1 and Ch 13,2.

1.7 Super high holding power (SHHP) anchors

1.7.1 The impact test requirements for SHHP anchor shackles are to be in accordance with the requirements for Grade U3 in Table 10.2.1.

1.8 Assembly

1.8.1 Assembly and fitting is to be carried out in accordance with the approved design.

1.8.2 Securing of anchor pins, shackle pins or swivels by welding is to be carried out by suitably qualified welders in accordance with an approved welding procedure.

1.9 Proof test of anchors

1.9.1 Anchors having a mass of 75 kg or more inclusive of stock (56 kg in the case of high holding power anchors) are to be tested in the presence of the Surveyor at a proving establishment recognised by LR. A list of recognised proving establishments is published separately by LR. In addition to the requirements stated in this Chapter, attention must be given to any relevant statutory requirements of the National Authority of the country in which the ship or mobile offshore unit is to be registered.

1.9.2 The anchor is to be visually examined before application of the proof test load to ensure that it is free from cracks, notches, inclusions and other surface defects that would impair the performance of the product.

1.9.3 As required by 1.9.1, each anchor is to be subjected to a proof loading test in an approved testing machine and is to withstand the load given in Table 10.1.1 for the appropriate mass of the anchor. The proof load is to be applied on the arm or on the palm at a spot which, measured from the extremity of the bill, is one-third of the distance between it and the centre of the crown. For stocked anchors, each arm is to be tested individually. For stockless anchors, both arms are to be tested at the same time, first on one side of the shank, then reversed and tested on the other.

Table 10.1.1 Proof load tests for anchors
(*see* Notes 1 and 2)

Mass of anchor (1.6.5) kg	Proof test load kN	Mass of anchor (1.6.5) kg	Proof test load kN	Mass of anchor (1.6.5) kg	Proof test load kN
50	23,2	2200	376,0	7800	861,0
55	25,2	2300	388,0	8000	877,0
60	27,1	2400	401,0	8200	892,0
65	28,9	2500	414,0	8400	908,0
70	30,7	2600	427,0	8600	922,0
75	32,4	2700	438,0	8800	936,0
80	33,9	2800	450,0	9000	949,0
90	36,3	2900	462,0	9200	961,0
100	39,1	3000	474,0	9400	975,0
120	44,3	3100	484,0	9600	987,0
140	49,0	3200	495,0	9800	998,0
160	53,3	3300	506,0	10 000	1010,0
180	57,4	3400	517,0	10 500	1040,0
200	61,3	3500	528,0	11 000	1070,0
225	65,8	3600	537,0	11 500	1090,0
250	70,4	3700	547,0	12 000	1110,0
275	74,9	3800	557,0	12 500	1130,0
300	79,5	3900	567,0	13 000	1160,0
325	84,1	4000	577,0	13 500	1180,0
350	88,8	4100	586,0	14 000	1210,0
375	93,4	4200	595,0	14 500	1230,0
400	97,9	4300	604,0	15 000	1260,0
425	103,0	4400	613,0	15 500	1280,0
450	107,0	4500	622,0	16 000	1300,0
475	112,0	4600	631,0	16 500	1330,0
500	116,0	4700	638,0	17 000	1360,0
550	125,0	4800	645,0	17 500	1390,0
600	132,0	4900	653,0	18 000	1410,0
650	140,0	5000	661,0	18 500	1440,0
700	149,0	5100	669,0	19 000	1470,0
750	158,0	5200	677,0	19 500	1490,0
800	166,0	5300	685,0	20 000	1520,0
850	175,0	5400	691,0	21 000	1570,0
900	182,0	5500	699,0	22 000	1620,0
950	191,0	5600	706,0	23 000	1670,0
1000	199,0	5700	713,0	24 000	1720,0
1050	208,0	5800	721,0	25 000	1770,0
1100	216,0	5900	728,0	26 000	1800,0
1150	224,0	6000	735,0	27 000	1850,0
1200	231,0	6100	740,0	28 000	1900,0
1250	239,0	6200	747,0	29 000	1940,0
1300	247,0	6300	754,0	30 000	1990,0
1350	255,0	6400	760,0	31 000	2030,0
1400	262,0	6500	767,0	32 000	2070,0
1450	270,0	6600	773,0	34 000	2160,0
1500	278,0	6700	779,0	36 000	2250,0
1600	292,0	6800	786,0	38 000	2330,0
1700	307,0	6900	794,0	40 000	2410,0
1800	321,0	7000	804,0	42 000	2490,0
1900	335,0	7200	818,0	44 000	2570,0
2000	349,0	7400	832,0	46 000	2650,0
2100	362,0	7600	845,0	48 000	2730,0
Proof loads for intermediate mass are to be determined by linear interpolation					

NOTES

1. Where ordinary anchors have a mass exceeding 48 000 kg, the proof loads are to be taken as 2,059 (mass of anchor in kg)$^{2/3}$ kN.
2. Where high holding power anchors have a mass exceeding 36 000 kg, the proof loads are to be taken as 2,452 (actual mass of anchor in kg)$^{2/3}$ kN.

1.9.4 The general arrangements for the test are to be such that the complete anchor, including the shackle, shackle pins and any welded or bolted connections are included in the test. If a replacement shackle is needed which requires welding or heating for fitting, the combined anchor and shackle are to be proof load tested. If welding or heating is not involved in fitting, the shackle may be proof load tested separately from the anchor.

1.9.5 The mass to be used in Table 10.1.1 is:

(a) For stockless anchors, the total mass of the anchor.
(b) For stocked anchors, the mass of the anchor excluding the stock.
(c) For high holding power anchors, a nominal mass equal to 1,33 times the actual total mass of the anchor.
(d) For mooring anchors, including positional mooring anchors, a nominal mass equal to 1,33 times the actual total mass of the anchor, unless specifically agreed otherwise.
(e) For super high holding power anchors, a nominal mass equal to twice the actual total mass of the anchor.

1.9.6 For positional mooring anchors, the proof test loading is to be that required by 1.9.3 or 50 per cent of the minimum break strength of the intended anchor line, whichever is the greater.

1.9.7 The gauge length is to be measured with 10 per cent of the required load applied, before and after proof test. The two measurements shall differ by no more than 1 per cent. The gauge length is the distance between the tip of each fluke and a point on the shank adjacent to the shackle pin, *see* Fig. 10.1.1.

1.9.8 After proof testing, all accessible surfaces are to be visually inspected by the Surveyor.

1.9.9 Following proof testing, NDE is to be conducted as described in Table 10.1.2 for ordinary and HHP anchors and Table 10.1.3 for SHHP anchors.

1.9.10 Each casting is to be subjected to ultrasonic inspection in the region of runners and risers, or where excess material has been removed by thermal methods. This examination is to extend around the whole periphery of the casting and for a distance of $t/3$ beyond the area affected, where t is the maximum thickness. In addition, random areas are to be selected by the Surveyor and examined.

1.9.11 Acceptance criteria for castings are to be in accordance with Chapter 4.

1.9.12 Acceptance criteria for forgings are to be in accordance with Chapter 5.

1.9.13 Paint or anti-corrosive coatings are not to be applied until these inspections are completed to the satisfaction of the Surveyor.

Table 10.1.2 NDE requirements following proof testing for Ordinary and HHP anchors

Location	Method of NDE
Feeder heads, runners and risers of castings	Magnetic particle inspection and ultrasonic test, *see* Note 1
All welds	Magnetic particle inspection
Forged components	Not required
Fabrication welds	Magnetic particle inspection

NOTES
1. *See also* 1.9.10.
2. Penetrant testing is to be used in lieu of magnetic particle testing for stainless steel, aluminium and copper alloy anchors.

Table 10.1.3 NDE requirements following proof testing for SHHP anchors

Location	Method of NDE
Feeder heads, runners and risers of castings	Magnetic particle inspection and ultrasonic test, *see* Note 1
All surfaces of castings	Magnetic particle inspection
All welds	Magnetic particle inspection
Forged components	Not required
Fabrication welds	Magnetic particle inspection

NOTES
1. *See also* 1.9.10.
2. Additionally, all surfaces of all SHHP anchors are to be surface inspected by the magnetic particle or penetrant method as appropriate.
3. Penetrant is to be used in lieu of magnetic particle testing for stainless steel, aluminium and copper alloy anchors.

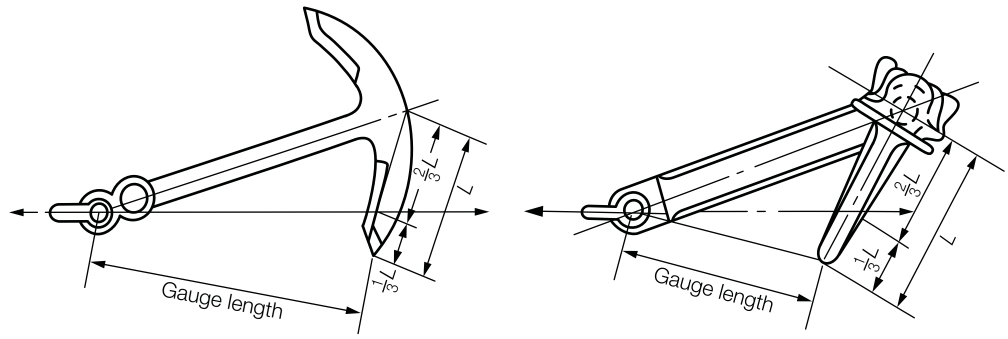


Fig. 10.1.1 Location of gauge length measurement during proof load

1.9.14 On completion of the proof testing, anchors made in more than one piece are to be examined for free movement of their heads over the complete range of rotation.

1.10 Clearances and tolerances

1.10.1 Where no fitting tolerances are specified on the approved plans the following assembly and fitting tolerance are to be applied.

1.10.2 The clearance either side of the shank within the shackle jaws and the shackle pin in the shank end hole is to be no more than 3 mm for small anchors up to 3 tonnes, 4 mm for anchors up to 5 tonnes, 6 mm for anchors up to 7 tonnes and is not to exceed 12 mm for larger anchors.

1.10.3 The shackle pin is to be a push fit in the eyes of the shackle, which are to be chamfered on the outside to ensure a good tightness when the pin is clenched over on fitting. The shackle pin to hole tolerance is to be no more than 0,5 mm for pins up to 57 mm and 1,0 mm for pins of larger diameter.

1.10.4 The trunnion pin is to be a snug fit within the chamber and be long enough to prevent horizontal movement. The gap is to be no more than 1 per cent of the chamber length.

1.10.5 The lateral movement of the shank is not to exceed 3 degrees from the centreline datum, *see* Fig. 10.1.2.

1.10.6 Unless otherwise agreed, the verification of mass and dimensions is the responsibility of the manufacturer. The Surveyor is only required to monitor this inspection. The mass of the anchor is to exclude the mass of the swivel, unless the swivel is in lieu of the conventional 'D' shackle.

1.11 Identification

1.11.1 Identification marks on the shank are to be approximately level with the fluke tips. On the fluke, these markings are to be approximately at a distance of two thirds from the tip of the bill to the centre line of the crown on the right hand fluke, looking from the crown towards the shank.

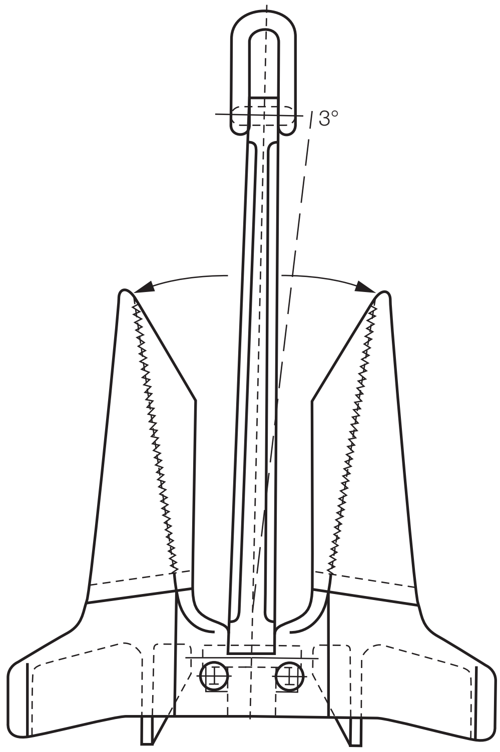


Fig. 10.1.2 Allowable lateral movement of shank

1.11.2 The following details are to be shown on all anchors:

(a) LR or Lloyd's Register and abbreviated name of LR's local office issuing the certificate.
(b) Number of the certificate.
(c) Month and year of test.
(d) Mass (also the letters 'HHP' when approved as high holding power anchors or 'SHHP' when approved as super high holding power anchors).
(e) Mass of stock (in the case of stocked anchors).
(f) National Authority requirements, as applicable.
(g) Manufacturer's mark.

1.11.3 In addition to 1.11.2, each important part of an anchor is to be plainly marked by the maker with the words 'forged steel' or 'cast steel' as appropriate. Fabricated steel anchor heads do not require special marking.

1.12 Certification

1.12.1 The manufacturer is to provide the Surveyor with a written statement that the anchor has been manufactured and tested in accordance with LR Rules together with the following particulars:

(a) Purchaser's name and order number.
(b) Type of anchor and principal dimensions.
(c) Mass of anchor.
(d) Identification mark which will enable the full history of manufacture to be traced.
(e) Chemical composition.
(f) Details of heat treatment.
(g) Mechanical test results.
(h) Proof load.
(j) Results of the non-destructive examination.
(k) Weld location maps (cast steel anchors only).

1.12.2 Shanks, heads, pins, shackles and swivels are to be certified by LR in accordance with the relevant sections of Chapters 3, 4 and 5.

1.12.3 An LR Anchor Certificate is to be issued for the completed anchor which will include the following particulars:

(a) Manufacturer's name.
(b) Type of anchor.
(c) Mass of anchor.
(d) Grade of materials.
(e) Proof test load.
(f) Heat treatment.
(g) Marking applied to anchor.
(h) Dimensions.
(j) General Approval of an Anchor Design Certificate Number.
(k) Fluke and shank identification numbers.

■ *Section 2* Stud link chain cables for ships

2.1 Scope

2.1.1 Provision is made in this Section for a range of grades, U1, U2 and U3, of stud link chain and fittings intended for anchor or mooring cables for ships.

2.1.2 The requirements for offshore mooring chain cables are given in Section 3.

2.1.3 The design of chain cables is to be to a Standard recognised by LR, such as ISO 1704.

2.2 Manufacture

2.2.1 All grades of chain cable and accessories are to be manufactured by approved procedures at works approved by LR. A list of approved manufacturers of stud link chain cables and fittings is published separately by LR.

2.2.2 The links may be made by the flash-butt or other approved welding process, or in the case of Grades U2 and U3 they may be flash-butt welded or drop forged, designated U2(a) or U3(a), or cast steel designated U2(b) or U3(b), *see* Table 10.2.5.

2.2.3 As far as practicable, consecutive links in all chain cable should originate from a single cast or batch of bar stock (*see* Ch 3,9.6.1), and indicating marks should be stamped on the final link formed from one cast or batch and the first link formed from a separate cast or batch.

2.2.4 A length of chain cable is to measure not more than 27,5 m and is to comprise an odd number of links. In this context, a length is a statutory term and is the basis for the number of test samples.

2.2.5 Where end links or enlarged links are manufactured and heat treated as part of and at the same time as the chain cable and are of the same cast heat of steel, they may be excluded from separate mechanical tests and break load tests.

2.3 Flash butt welded chain cable

2.3.1 Bar material is to comply with the requirements of Ch 3,9 and may be heated either by electrical resistance or in a furnace. For electrical resistance heating, the process is to be controlled by an optical heat sensor. For furnace heating, thermocouples in close proximity to the bars are to be used for control. The temperature is to be continuously recorded. In both cases, the controls are to be checked at least once every eight hours and checks are to be recorded.

2.3.2 Mechanical properties testing of U1 cable is not required. For Grade U2 cable supplied in the as-welded condition, and Grade U3 in all conditions, one tensile and one set of three Charpy V-notch impact test specimens are to be taken at the side of a link opposite the weld from at least every fourth 27,5 m length of cable. A further set of three impact test specimens is to be taken with the notch positioned at the centre of the weld, *see* Table 10.2.3. The test specimens are not to be selected from the same length as that from which the breaking test sample is taken, unless breaking test samples are to be taken from every length of the batch. All test samples are to be correctly identified with the lengths of cable represented.

2.3.3 The test links from which the mechanical test specimens are prepared are to be made as part of the chain cable and are to be heat treated with it. They may be removed from the cable prior to heat treatment provided that each sample is heat treated with, and in the same manner as, the chain it represents prior to preparation of the mechanical test specimens.

2.3.4 The results of tests on specimens taken from the non-welded areas are to comply with the appropriate requirements of Table 10.2.1. The results of tests on the welds are to comply with the requirements of Table 10.2.6.

2.4 Cast chain cables

2.4.1 The manufacture of cast steel chain cable is generally to be in accordance with the requirements of Ch 4,1, as appropriate.

2.4.2 The chemical composition of ladle samples is to comply with the specification approved by LR.

2.4.3 Separately cast test samples are to be provided from each cast. They are to be of similar dimensions to the links they represent and are to be heat treated together with, and in the same manner as, the completed chain cable, *see* Table 10.2.3.

2.4.4 Tensile and Charpy V-notch impact test specimens are to be taken from each test sample and machined to the dimensions given in Ch 2,3.

2.4.5 The results of all tests are to comply with the requirements given in Table 10.2.1 for the relevant grade.

2.5 Forged chain cables

2.5.1 The procedure for the manufacture and testing of drop forgings for chain cable will be specially considered, but is generally to be in accordance with the appropriate requirements of Ch 5,1.

2.5.2 The chemical composition is to comply with Table 10.2.2.

2.5.3 The completed forgings are to be heat treated in accordance with Table 10.2.3.

2.5.4 Test samples are to be provided in the form of forgings of similar dimensions to the links they represent. These test samples are to be from the same steel-making heat and heat treated together with the links they represent.

2.5.5 One tensile and three Charpy V-notch specimens are to be taken from each test sample.

2.5.6 The results of mechanical tests are to comply with the requirements of Table 10.2.1 for the relevant grade.

Table 10.2.1 Mechanical properties of finished chain cable and fittings

Grade	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on $5,65\sqrt{S_o}$ % minimum	Reduction of area % minimum	Charpy V-notch impact tests	
					Test temperature °C	Average energy J minimum
U2	295	490 – 690	22	—	0 (*see* Note 1)	27
U3	410	690 minimum	17	40	0 –20 (*see* Note 2)	60 35

NOTES
1. When required *see* Table 10.2.3.
2. Testing may be carried out at either 0°C or –20°C.
3. Mechanical testing is not required for finished chain cables and fittings in Grade U1.

Table 10.2.2 Chemical composition of butt welded and forged chain cable

Grade	Chemical composition %												
	C max.	Si	Mn	P max.	S max.	Al	N max.	Cr max.	Cu max.	Nb max.	Ni max.	V max.	Mo max.
U1	0,20	0,15 – 0,35	0,40 min.	0,04	0,04	—	—	—	—	—	—	—	—
U2	0,24	0,15 – 0,55	1,60 max.	0,035	0,035	0,02 min. *see* Note 1	—	—	—	—	—	—	—
U3	0,33	0,15 – 0,35	1,90 max.	0,04	0,04	0,065 max. *see* Note 2	0,015	0,25	0,35	0,05 *see* Note 2	0,40	0,10 *see* Note 2	0,08

NOTES
1. Aluminium may be partly replaced by other grain refining elements.
2. To obtain fine grain steel, at least one of these grain refining elements must be present in sufficient amount.

Table 10.2.3 Condition of supply and scope of mechanical tests for finished chain cables and fittings

Grade	Manufacturing method	Condition of supply	Number of test specimens on every four lengths of chain cable of 27,5 m or less, or on each batch of fittings		
			Tensile test on base materials	Charpy V-notch impact test	
				Base material	Weldment
U1 cable	Flash butt welded	As welded Normalised	— —	— —	— —
U2 cable	Flash butt welded	As welded Normalised	1 —	3 —	3 —
U3 cable	Flash butt welded	Normalised Normalised and Tempered Quenched and Tempered	1	3	3
U2 cable	Cast or drop forged	Normalised	1	3	—
U3 cable	Cast or drop forged	Normalised Normalised and Tempered Quenched and Tempered	1	3	—
U2 fittings	Cast or drop forged	Normalised	1	3	—
U3 fittings	Cast or drop forged	Normalised Normalised and Tempered Quenched and Tempered	1	3	—

2.6 Stud material

2.6.1 Steel studs are to be used for all grades of welded chain cable. In general, the carbon content should not exceed 0,23 per cent but mechanical tests for acceptance purposes are not required.

2.7 Welding of studs

2.7.1 Where studs are welded into the links this is to be completed before the chain cable is heat treated.

2.7.2 The stud ends must be a good fit inside the link, and the weld is to be confined to the stud end opposite the flash-butt weld. The full periphery of the stud end is to be welded. If, however, it can be demonstrated to the Surveyor that the quality of welding is of a high standard then partial peripheral welding may be accepted provided that welds are made only at the sides of the stud and that each run extends continuously for at least 25 per cent of the stud periphery. Weld start/stop positions are not to be located in the plane of the chain cable.

2.7.3 The welds are to be made by qualified welders using an approved procedure and consumables approved to Grade 3 and low hydrogen, in accordance with Chapter 11.

2.7.4 The welds are to be of good quality and free from defects liable to impair the proper use of the chain. Undercuts, end craters and similar stress raising defects shall, where necessary, be ground off.

2.7.5 At least one stud weld within each length of cable is to be inspected using dye penetrant testing in accordance with Ch 1,5 after the chain has been proof loaded. If a crack is found, the stud welds in the adjoining links are to be inspected; if a crack is found in either link, all the stud welds in that length are to be inspected using dye penetrant.

2.7.6 The size of the stud welds is to be in accordance with Fig. 10.3.1.

2.8 Heat treatment of completed chain cables

2.8.1 The completed chain cable is to be heat treated in accordance with Table 10.2.3 for the appropriate grade of cable.

2.8.2 Special consideration will be given to the heat treatment of certain types of drop forged chain cable.

2.8.3 In all cases, heat treatment is to be carried out prior to the proof loading and breaking tests.

2.8.4 All test samples are to be heat treated with, and in the same way as, the chain cables they represent.

2.9 Testing of completed chain cables

2.9.1 All chain cables are to be subjected to a Proof Load test and a Breaking Load test. In addition, mechanical tests should be carried out where required, *see* Table 10.2.3.

2.9.2 All chain cables are to be tested in the presence of a Surveyor, at a proving establishment recognised by LR. A list of recognised proving establishments is published separately by LR. In addition to the requirements stated in this Chapter, attention must be given to any relevant statutory requirements of the National Authority of the country in which the ship is to be registered.

2.10 Proof load tests

2.10.1 Each length of chain cable is to be subjected to a proof loading test in an approved testing machine and is to withstand the load given in Table 10.2.4 for the appropriate grade and size of cable.

2.10.2 On completion of the test, each link is to be visually examined and is to be free from significant defects. Special attention is to be given to welds.

2.10.3 Should any link be found to be defective it is to be replaced by an approved connecting link (joining shackle or substitute link as detailed in 2.14). The chain is then to be subjected to a repeat of the proof load test followed by re-examination.

2.10.4 If a link breaks during proof load testing, a sample consisting of three common links is to be taken from each side of the broken link and subjected to a breaking test as detailed in 2.10. If either of these samples fails, the length of cable is not to be accepted. A thorough examination of all broken links is to be made to determine the cause of failure and, after evaluation, LR will consider the extent of cable which is to be rejected.

2.11 Breaking load tests

2.11.1 Breaking load tests are to be carried out on three-link samples selected by the Surveyor from the completed (including heat treatment) chain. The test links may be removed from the chain prior to heat treatment provided that each sample is heat treated with, and in the same manner as the chain it represents. They are to be properly identified with the lengths of chain they represent.

2.11.2 The number of tests required is to be in accordance with Table 10.2.5 except that for chafing chain for Emergency Towing Arrangements (ETA), *see* Pt 3, Ch 13,10.2, one test is to be carried out on each 110 m of finished chains.

2.11.3 Breaking test specimens are to withstand the load given in Table 10.2.4 for the appropriate grade and size of cable. The specimen is considered to have passed this test if it has shown no sign of fracture after application of the required load for a minimum of 30 seconds.

2.11.4 Where a breaking test specimen fails, a further specimen is to be cut from the same length of cable and subjected to test. If this re-test fails, the length of cable from which it was taken is to be rejected. When this test is also representative of other lengths, each of the remaining lengths is to be individually tested by taking a breaking test specimen from each length of the batch. If one of these further tests fails, the entire set of lengths represented by the original test is to be rejected.

2.11.5 For large diameter cables where the required breaking load is greater than the capacity of the testing machines, special consideration will be given to acceptance of an alternative testing procedure.

2.12 Dimensional inspection

2.12.1 After proof testing, the entire chain is to be checked for length, five links at a time with an overlap of two links, which is to include the first five links, to ensure that the chain meets the tolerances given in 2.15.5. The measurements are to be made while the chain is loaded to about 10 per cent of the proof load.

2.12.2 The links held in the end blocks may be excluded from these measurements.

2.12.3 If a five link length of chain exceeds the tolerance given in 2.15.5, then the oversize links are to be removed and an approved connecting link inserted.

2.12.4 Checks of all other dimensions are to be made on three links, selected by the Surveyor, from every four 27,5 m lengths.

2.12.5 If one of the links detailed in 2.12.4 fails to comply with the required tolerances, measurements are to be made on a further five links in every four 27,5 m lengths.

2.12.6 If more than one link in a 27,5 m length of chain cable fails to meet the tolerance requirements, all the links in that length are to be measured.

2.12.7 All links failing to comply with the maximum dimensional tolerances are to be removed and replaced by connecting links of an approved type. The chain is then to be subjected to a further proof load test and re-examined.

2.12.8 If the length over five links is less than the nominal, then the chain may be stretched by loading above the specified proof test load provided that the applied load is not greater than ten per cent above the proof test load, and only random lengths of the chain need to be stretched.

2.12.9 Loads used for plastic straining to set studs are not to exceed 0,8 per cent of the proof load unless specifically approved for higher loads.

2.12.10 Paint or anti-corrosive coatings are not to be applied until these inspections are completed to the satisfaction of the Surveyor.

Table 10.2.4 Test loads for stud link anchor chain cables

Chain diameter	Grade U1		Grade U2		Grade U3	
	Proof load kN	Breaking load kN	Proof load kN	Breaking load kN	Proof load kN	Breaking load kN
d mm	$0{,}00686d^2$ $(44-0{,}08d)$	$0{,}00981d^2$ $(44-0{,}08d)$	$0{,}00981d^2$ $(44-0{,}08d)$	$0{,}01373d^2$ $(44-0{,}08d)$	$0{,}01373d^2$ $(44-0{,}08d)$	$0{,}01961d^2$ $(44-0{,}08d)$
12,5	46	66	66	92	—	—
14	58	82	82	115	—	—
16	75	107	107	150	—	—
17,5	89	128	128	179	—	—
19	105	150	150	211	—	—
20,5	122	175	175	244	244	349
22	140	201	201	281	281	401
24	166	238	238	333	333	475
26	194	278	278	389	389	556
28	225	321	321	450	450	642
30	257	367	367	514	514	734
32	291	416	416	583	583	832
34	327	468	468	655	655	936
36	366	523	523	732	732	1045
38	406	580	580	812	812	1160
40	448	640	640	896	896	1280
42	492	703	703	984	984	1406
44	538	769	769	1076	1076	1537
46	585	837	837	1171	1171	1673
48	635	908	908	1270	1270	1814
50	686	981	981	1373	1373	1961
52	739	1057	1057	1479	1479	2113
54	794	1135	1135	1589	1589	2269
56	850	1216	1216	1702	1702	2430
58	908	1299	1299	1818	1818	2597
60	968	1384	1384	1938	1938	2767
62	1029	1472	1472	2060	2060	2943
64	1092	1562	1562	2187	2187	3123
66	1157	1655	1655	2316	2316	3308
68	1223	1749	1749	2448	2448	3496
70	1291	1846	1846	2583	2583	3690
73	1395	1995	1995	2792	2792	3988
76	1503	2149	2149	3007	3007	4295
78	1576	2254	2254	3154	3154	4505
81	1689	2415	2415	3380	3380	4827
84	1805	2580	2580	3612	3612	5158
87	1923	2750	2750	3849	3849	5498
90	2045	2924	2924	4093	4093	5845
92	2127	3042	3042	4258	4258	6081
95	2254	3223	3223	4510	4510	6442
97	2339	3345	3345	4682	4682	6687
100	2470	3532	3532	4943	4943	7060
102	2558	3658	3658	5120	5120	7312
105	2692	3850	3850	5389	5389	7697
107	2783	3980	3980	5571	5571	7957
111	2968	4245	4245	5941	5941	8486
114	3110	4447	4447	6224	6224	8889
117	3253	4652	4652	6511	6511	9299
120	3398	4859	4859	6801	6801	9714
122	3496	4999	4999	6997	6997	9994
124	3595	5141	5141	7195	7195	10276
127	3744	5354	5354	7494	7494	10703
130	3895	5571	5571	7796	7796	11135
132	3997	5716	5716	8000	8000	11426
137	4254	6083	6083	8514	8514	12161
142	4515	6456	6456	9036	9036	12906
147	4779	6834	6834	9565	9565	13662
152	5046	7217	7217	10100	10100	14426
157	5316	7602	7602	10640	10640	15197
162	5588	7991	7991	11185	11185	15975

Table 10.2.5 Number of breaking tests from completed cables

Designation	Method of manufacture	Number of breaking test specimens
Grade U1	Flash-butt welded and heat treated	One from every four lengths of 27,5 m or less
Grade U2(a) U3(a)	Flash-butt welded, or drop forged and heat treated	One from every four lengths of 27,5 m or less
Grade U1 U2(a)	Flash-butt welded but not heat treated	One from each length of 27,5 m or less
Grade U2(b) U3(b)	Cast and heat treated	One per heat treatment batch with a minimum of one from every four lengths of 27,5 m or less

Table 10.2.6 Mechanical properties of welds in chain cables

Grade	Charpy V-notch impact test	
	Test temperature °C	Average energy J min
U1	—	—
U2	0 (*see* Note 1)	27
U3	0	50
	–20 (*see* Note 2)	27

NOTES
1. Impact tests are only required if the chain cable is not heat treated.
2. Impact testing may be carried out at 0°C or minus 20°C.

2.13 Fittings for chain cables

2.13.1 Cable fittings are to be manufactured at an approved works.

2.13.2 The materials from which the fittings are made are to be manufactured at approved works, in accordance with the appropriate requirements of Ch 4,1 or Ch 5,1 respectively. Alternative arrangements may be agreed provided that full details concerning the manufacturer are submitted to LR.

2.13.3 All fittings are to be manufactured to an approved manufacturing specification, and provision is to be made for tensile specimens and, where applicable, impact test specimens, *see* Table 10.2.3. The mechanical test requirements are the same as those for the relevant grade of chain cable, *see* Table 10.2.1.

2.13.4 The test samples are to be prepared in accordance with 2.4.3 or 2.5.4 as applicable. The test specimens are to be subjected to heat treatment with the fittings they represent.

2.13.5 A batch of fittings is to be of the same grade, size and heat treatment furnace load and is to have originated from a single cast heat of steel.

2.13.6 Mechanical tests of pins are to be taken in accordance with 3.8.15.

2.13.7 Fittings such as shackles, swivels and swivel shackles are to be forged or cast in steel of at least Grade U2. The welded construction of fittings may also be approved providing that full details of the manufacturing process and the heat treatment are submitted.

2.13.8 All chain cable accessories, including spares, are to be subjected to the proof loads appropriate to the grade and size of cable for which they are intended. These include shackles, swivels, swivel shackles, enlarged links and end links. Anchor shackles, however, are to be tested in combination with the anchor, *see* 1.4.

2.13.9 The appropriate breaking load is to be applied for a minimum of 30 seconds to at least one item out of every batch of up to 25 detachable links, shackles, swivels, swivel shackles, enlarged end links and end links and at least one item out of every batch of up to 50 for lugless (Kenter) shackles. The item tested is to be destroyed and not used as part of an outfit. For the purposes of break load testing, a batch of accessories is to consist of:

(a) the same accessory type, grade and size;
(b) the same rolling or forging or casting process; and
(c) accessories that are heat treated together in the same furnace.

2.13.10 Where a break load batch as defined in 2.13.9 requires a normalise or normalise and temper heat treatment, the size of accessories may vary within a batch provided that the heat treatment cycle is chosen to satisfy the accessory with the largest cross-section size. The batch may consist of more than one steel-making heat provided that the two accessories are break tested, one with the largest cross-section size and one with the smallest cross-section size.

2.13.11 Where a break load batch as defined in 2.13.9 requires a quench and temper heat treatment, the size of the accessories within the batch is to be the same and is limited to the same steel-making heat.

2.13.12 If the sample fails to withstand the breaking load without fracture, two more samples from the same batch may be tested. If either of these samples fails, the batch is to be rejected.

2.13.13 Fittings of increased dimensions or higher grade material may be used subject to approval by LR.

2.13.14 Where items of increased dimensions are used or if material of a higher grade than is specified is used, the breaking load is to be applied to each item, and the items so tested included with the outfit. For the purpose of this paragraph, items of increased dimensions are those so designed that their breaking strength is not less than 1,4 times the Rule minimum breaking load of the chain cable with which they are to be used.

2.13.15 LR may waive the breaking load test provided that:

(a) the breaking load test has been completed satisfactorily during approval testing, and

(b) the tensile and impact properties of each manufacturing batch are proved and

(c) the accessories are subjected to suitable non-destructive testing.

2.13.16 All testing is to be carried out in the presence of the Surveyor and to his satisfaction.

2.13.17 All fittings are to be stamped in accordance with 2.16.

2.14 Substitute single links

2.14.1 Single links to connect lengths of chain cable or to substitute for defective links, without the necessity for re-heat treatment of the whole cable length, are to be made by the chain manufacturer in accordance with an approved procedure. Separate approvals are required for each grade of chain cable and the tests are to be made on the maximum size of chain for which approval is sought. Re-approval is required annually.

2.14.2 Manufacture and heat treatment of the substitute link are not to affect the strength of the adjoining links. The temperature reached by these links is nowhere to exceed 250°C.

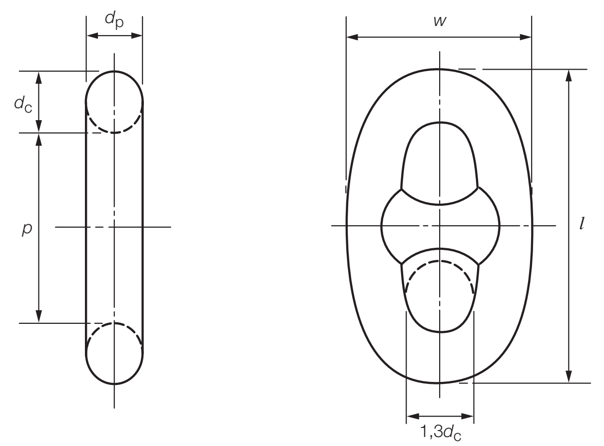
2.14.3 The steel bar used is to conform with the specification for the chain in accordance with Ch 3,9.

2.14.4 Details of the method of manufacture, including heat treatment, are to be submitted for approval, together with the results of a series of tests laid down by LR.

2.14.5 All links involved in the approval tests are to be destroyed and are not to be used as part of a chain cable.

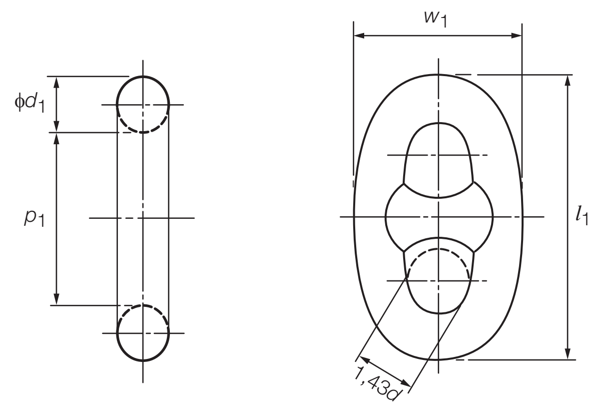
2.14.6 Every substitute link included in a chain cable is to be subjected to the proof load appropriate to the grade and size of chain in which it is incorporated, as detailed in Table 10.2.4.

2.14.7 Each substitute link is to be stamped on the stud with the identification marks listed in 2.16.1 plus a unique number for the link. The adjoining links are also to be stamped on the studs.



d = nominal diameter $\left(\frac{d_c + d_p}{2}\right)$
d_c = nominal diameter at crown measured in plane of link
d_p = nominal diameter at crown measured perpendicular to plane of link
l = $6d_c$
p = $4d_c$
w = $3,6d_c$ to the nearest millimetre

Fig. 10.2.1 Common link



d = nominal diameter of common stud link
d_1 = nominal diameter of enlarged stud link = $1,1d$
l_1 = $6d_1 \approx 6,6d$
p_1 = $4d_1 \approx 4,4d$
w_1 = $3,6d_1 \approx 3,96d$

Fig. 10.2.2 Enlarged link

2.15 Dimensions and tolerances

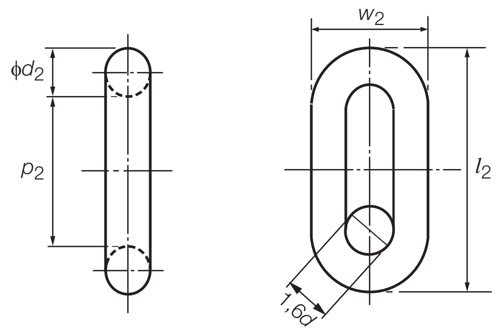
2.15.1 The form and proportion of links and shackles are to be in accordance with ISO/1704-2008, *see* Figs. 10.2.1 to 10.2.8. Design of chain cables must be to a standard recognised by LR, such as ISO 1704; alternatively the design may be specifically approved by LR.

2.15.2 Manufacturing tolerances on stud link chain are to be within ±2,5 per cent (taking into account that all components of the chain are to be a good fit with one another), except for those detailed in 2.15.3.

2.15.3 The nominal diameter, d, is to be the average of the diameters, measured in the plane of the link, d_c, and perpendicular to the plane of the link, d_p, *see* Fig. 10.2.1. The negative tolerance on the nominal diameter is not to exceed the following:

Minus 1 mm when $d \leq 40$ mm
Minus 2 mm when 40 mm $< d \leq 84$ mm
Minus 3 mm when 84 mm $< d \leq 122$ mm
Minus 4 mm when $d > 122$ mm

The plus tolerance on the diameter at the crown measured out of the plane of the link, d_p, is not to exceed 5 per cent.



d = nominal diameter of common stud link
d_2 = nominal diameter of end link = 1,2d (d_2 = 1,2d)
l_2 = $p_2 + 2d_2 \approx 6{,}75d$
p_2 = $3{,}65d_2 \approx 4{,}35d$
w_2 = $3{,}3d_2 \approx 4d$

Fig. 10.2.3 End link

2.15.4 The cross-sectional area is to be calculated using the nominal diameter, d. The cross-sectional area at the crown of the link is to have no negative tolerance.

2.15.5 The diameter measured at locations other than the crown is to have no negative tolerance. The plus tolerance is to be in accordance with Table 3.9.3 of Chapter 3 except at the butt weld where it is to be in accordance with the manufacturer's specification, which is to be agreed by LR.

2.15.6 The maximum allowable tolerance on a length of five links measured in accordance with 2.12.1 is plus 2,5 per cent. No under-tolerance is permitted.

2.15.7 All measurements are to be made on links selected by the Surveyor and are to be carried out to the Surveyor's satisfaction.

2.15.8 Studs are to be located in the links centrally, and at right angles to the sides of the link, although the studs of the final link at each end of any length may also be located off-centre to facilitate the insertion of the joining shackle. Tolerances in accordance with Fig. 10.3.1 are acceptable provided that the stud fits snugly and its ends lie flush against the inside of the link.

2.15.9 The following tolerances are applicable to accessories:

Nominal diameter: plus 5 per cent, minus 0 per cent
Other dimensions: ±2,5 per cent.

2.15.10 For lugless shackles of the Kenter type, the radii indicated in Fig. 10.2.8 are to be not less than 0,03 times the chain diameter.

2.15.11 All materials are to be free from internal and surface defects that might impair proper workability, use and strength. Subject to agreement by the Surveyor, surface defects may be removed by grinding provided the acceptable tolerances are not exceeded.

2.16 Identification

2.16.1 All lengths of Grades U1, U2 and U3 cable and all fittings are to be stamped with the following identification marks:

(a) LR or Lloyd's Register and abbreviated name of LR's local office issuing the certificate.
(b) Number of certificate.
(c) Proof load and grade of chain.
(d) Surveyor's personal stamp.
(e) Each length of chain cable is to be stamped on both ends.

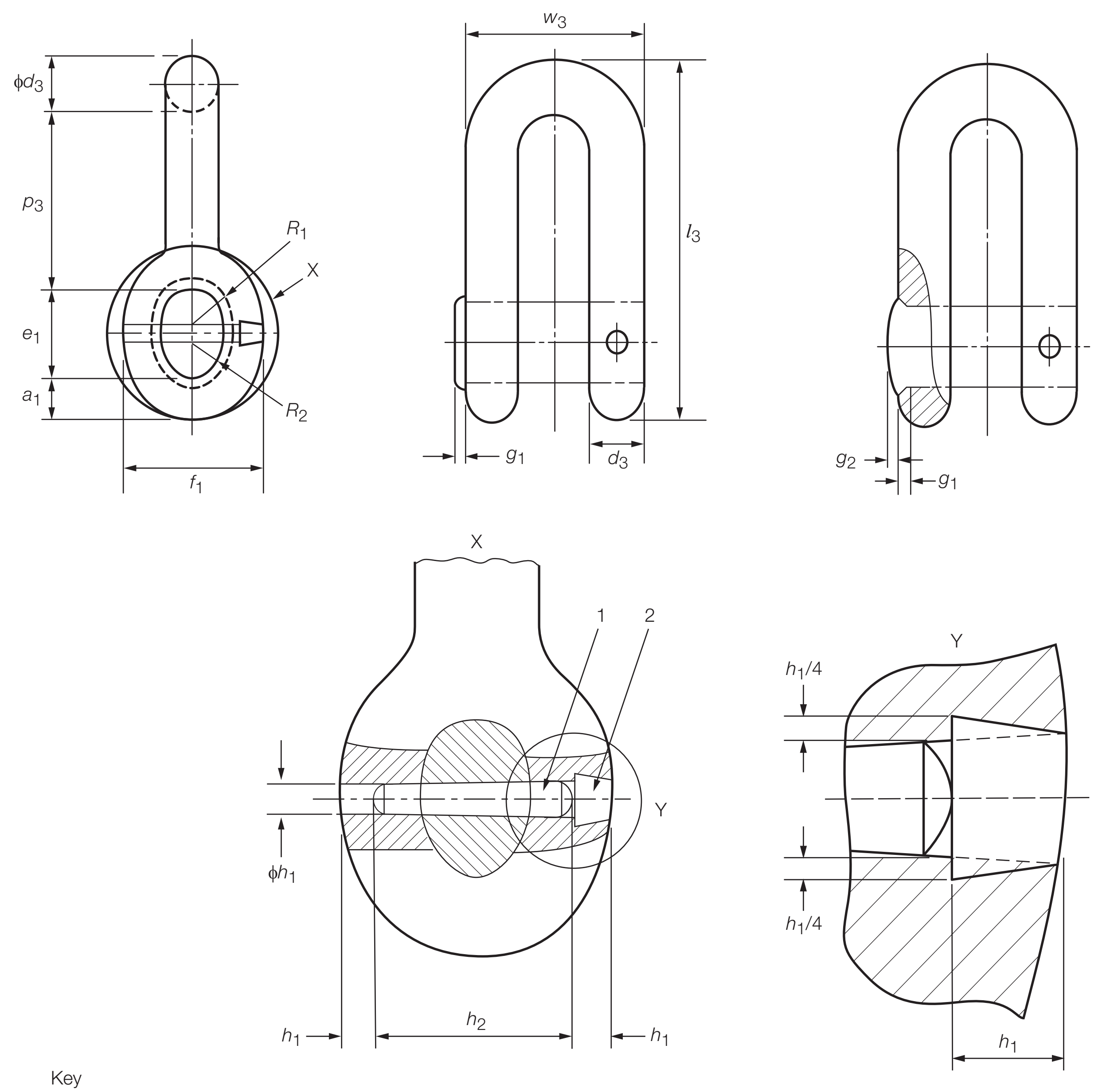
2.17 Certification

2.17.1 An LR certificate is to be issued for chain cable only, fittings only or chain cable with associated fittings.

2.17.2 Each test certificate is to include the following particulars for all items included on the certificate:

(a) Purchaser's name and order number.
(b) Description and dimensions.
(c) Grade of chain cable.
(d) Identification mark which will enable the full history of the chain or fitting to be traced.
(e) Chemical composition.
(f) Details of heat treatment.
(g) Mechanical test results.
(h) Breaking test load.
(j) Proof load.

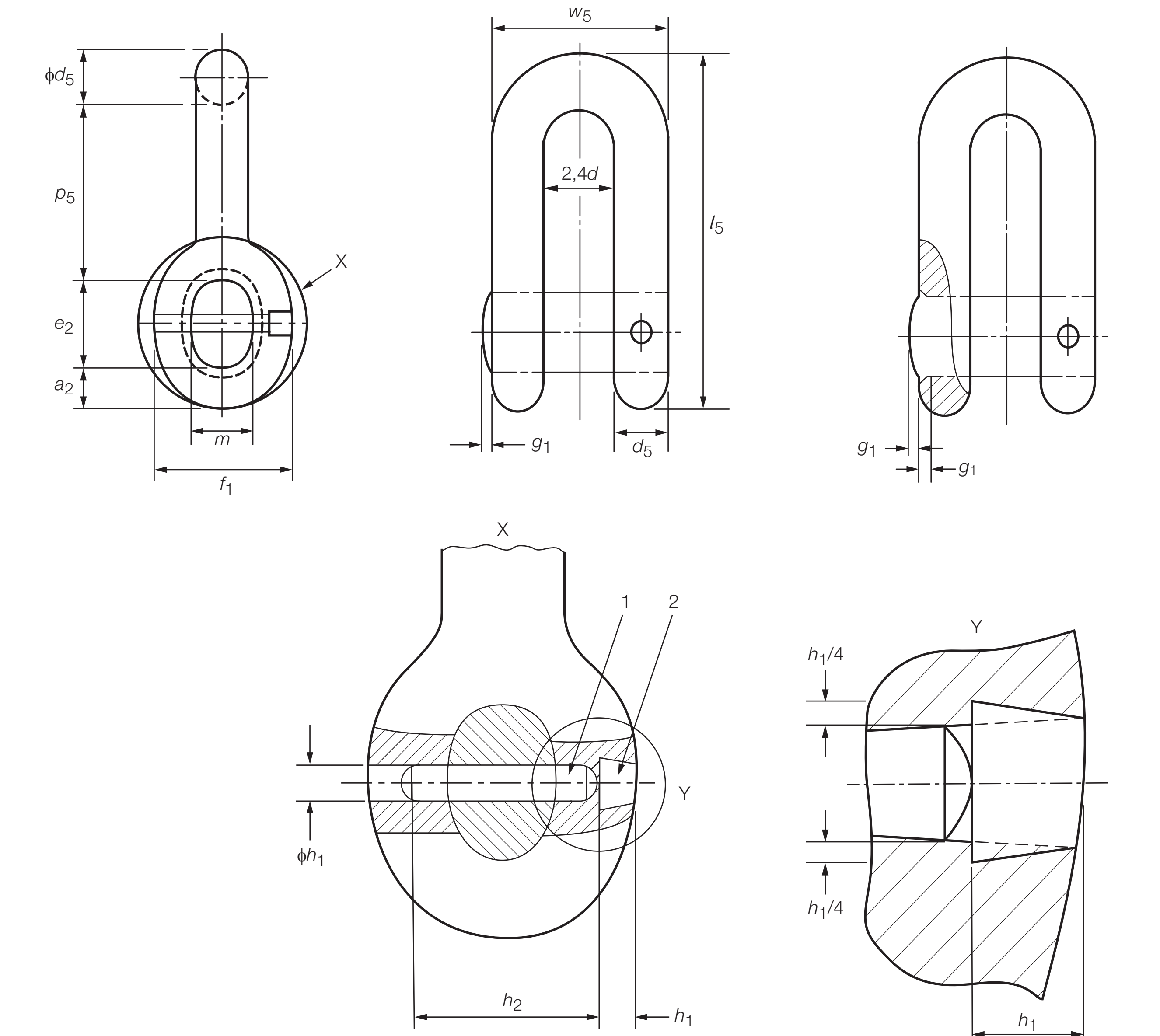
2.17.3 Where appropriate, the certificate is to include a list of all substitute links together with their grade of steel, the name of the steelmaker, the heat number and the purchase order number.



Key
1 retaining pin
2 dovetail chamber

d	=	nominal diameter of common stud link	f_1	=	2,8d
d_3	=	nominal diameter of joining shackle = 1,3d	g_1	=	0,2d
l_3	=	7,1d	g_2	=	0,1d
p_3	=	$l_3 - (d_3 + a_1 + e_1) = 3{,}4d$	h_1	=	nominal diameter of taper pin
w_3	=	4d	h_2	=	nominal length of taper pin
a_1	=	0,8d	R_1	=	0,6d
e_1	=	1,6d	R_2	=	0,5d

Fig. 10.2.4 Dee shackle

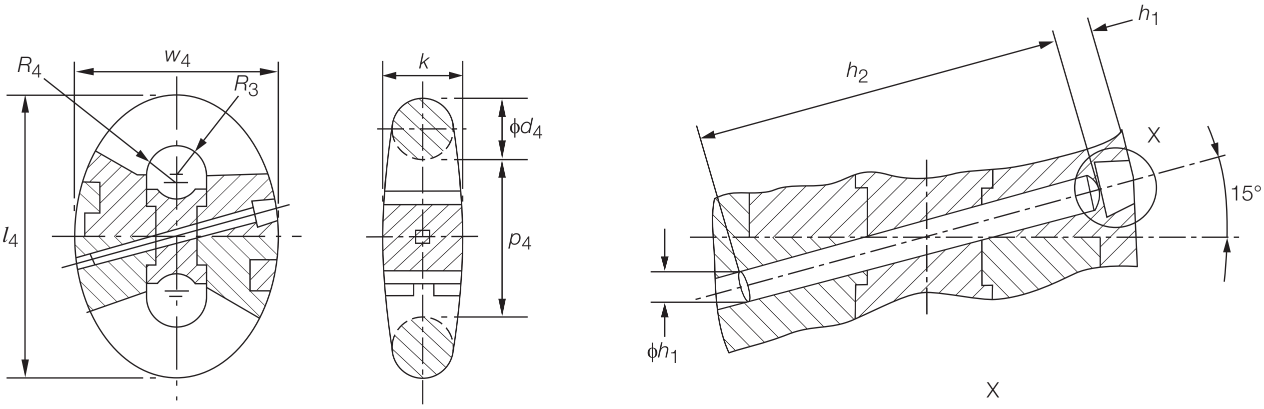


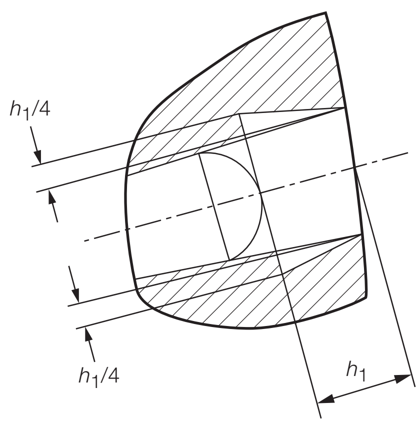
Key
1 retaining pin
2 dovetail chamber

d = nominal diameter of common stud link
d_5 = nominal diameter of end shackle = 1,4d
l_5 = 8,7d
p_5 = $l_5 - (d_5 + a_2 + e_2)$ = 4,6d
w_5 = 5,2d
a_2 = 0,9d
e_2 = 1,8d

f_2 = 3,1d
g_1 = 0,2d
g_2 = 0,1d
m = 1,4d
h_1 = nominal diameter of taper pin
h_2 = nominal length of taper pin

Fig. 10.2.5 End shackle



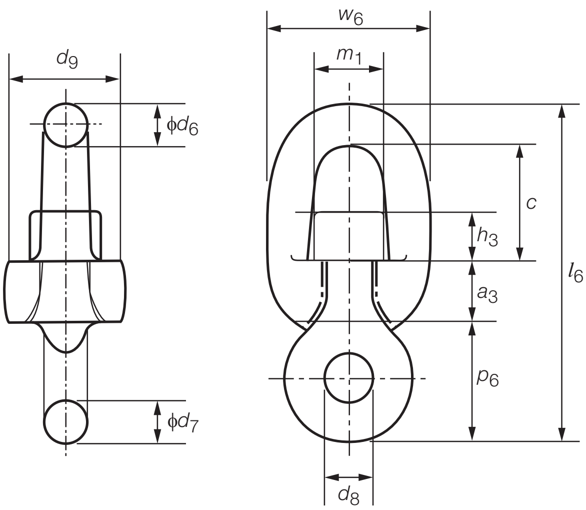


Key

X = dovetail chamber for retaining pellet

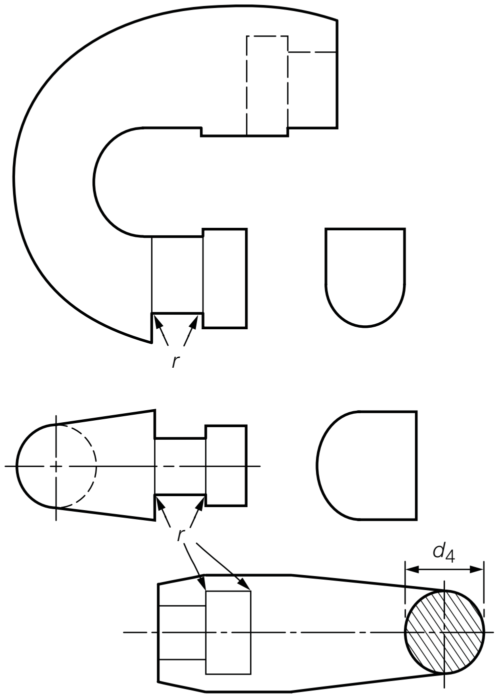
d = nominal diameter of common stud link
d_4 = nominal diameter of Kenter type joining shackle = d
l_4 = $6d$
p_4 = $4d$
w_4 = $4{,}2d$
h_1 = nominal diameter of taper pin
h_2 = nominal length of taper pin
k = $1{,}52d$
R_3 = $0{,}67d$
R_4 = $1{,}83d$

Fig. 10.2.6 Lugless shackle



d = nominal diameter of common stud link
d_6 = nominal diameter of swivel = $1{,}2d$
l_6 = $9{,}7d$
p_6 = $d_9 = 3{,}4d$
w_6 = $4{,}7d$
d_7 = $1{,}1d$
a_3 = $1{,}75d$
m_1 = $2d$
h_3 = $d_8 = 1{,}4d$
c = $3{,}35d$

Fig. 10.2.7 Swivel



The radii indicated by r are to be not less than 0,03 x d_4

Fig. 10.2.8 Lugless shackle of the Kenter type

Section 3 Stud link mooring chain cables

3.1 Scope

3.1.1 Provision is made in this Section for five grades, R3, R3S, R4, R4S and R5, of stud link chain intended for offshore mooring applications such as mooring of mobile offshore units, offshore loading systems and gravity based structures during fabrication.

3.1.2 Design of chain cables must be to a recognised Standard, such as ISO 1704; alternatively, the design may be specifically approved by LR.

3.1.3 In addition, chain cable conforming to the requirements of the current edition of API specification 2F is acceptable provided that it has been manufactured, inspected and tested under Survey by LR, and that the bar stock has also been certified by LR in accordance with Ch 3,9.

3.2 Manufacture

3.2.1 All grades of chain cable and accessories are to be manufactured by approved procedures at works approved by LR. A list of approved manufacturers for stud link chain cables is published separately by LR.

3.2.2 The works in which the chain is manufactured is to have a quality system approved by LR. The provision of such a quality system is required in addition to and not in lieu of the witnessing of tests by a Surveyor.

3.2.3 Approval is confined to a single works and is limited to one grade of cable made from bar from a nominated and approved supplier. Separate approvals are required if steel bar is supplied from more than one works and for other grades of cable, *see also* Ch 3,9.

3.2.4 Details of the method of manufacture and the specification of the steel, are to be submitted.

3.2.5 Offshore mooring chains are to be made in continuous lengths by flash-butt welding.

3.2.6 Bar material may be heated either by electric resistance or in a furnace. For electrical resistance heating, the process is to be controlled by an optical heat sensor. For furnace heating, thermocouples in close proximity to the bars are to be used for control and the temperature is to be continuously recorded. In both cases, the controls are to be checked at least once every eight hours and records taken.

3.2.7 The following welding parameters (as approved in the weld procedure) are to be controlled during welding of each link:

(a) platen motion;
(b) current as a function of time; and
(c) hydraulic pressure.

The controls are to be checked at least once every four hours.

3.2.8 The records of bar heating, flash-butt welding and heat treatment are to be made available to the Surveyor when required.

3.2.9 As far as practicable, consecutive links in all chain cable should originate from a single batch of bar stock (*see* Ch 3,9.6.1) and indicating marks should be stamped on the final link formed from one batch and the first link formed from a separate batch.

3.3 Dimensions and tolerances

3.3.1 The form and proportions of links and shackles are to be in accordance with ISO/1704, *see* Figs. 10.2.1 to 10.2.8. Link tolerances are to be in accordance with 3.3.2 to 3.3.6.

3.3.2 Diameter measured at the crown:

Minus 1 mm when $d_c \le 40$ mm
Minus 2 mm when 40 mm $< d_c \le 84$ mm
Minus 3 mm when 84 mm $< d_c \le 122$ mm
Minus 4 mm when 122 mm $< d_c \le 152$ mm
Minus 6 mm when 152 mm $< d_c \le 184$ mm
Minus 7,5 mm when 184 mm $< d_c \le 210$ mm

The plus tolerance must not exceed 5 per cent of the nominal diameter, and the cross-sectional area at the crown is to have no negative tolerance.

3.3.3 The diameter measured at locations other than the crown is to have no negative tolerance. The plus tolerance is to be in accordance with Table 3.9.3 except at the butt weld where it is to be in accordance with the manufacturer's specification, which is to be agreed by LR.

3.3.4 The maximum allowable tolerance on a length of five links measured in accordance with 2.12.1 is +2,5 per cent. No under-tolerance is permitted.

3.3.5 A manufacturing tolerance on all other dimensions of ±2,5 per cent is acceptable subject to all parts fitting properly together.

3.3.6 The tolerances for common links are to be measured in accordance with Fig. 10.3.3.

3.3.7 All measurements are to be made on links selected by the Surveyor and are to be carried out to the Surveyor's satisfaction.

3.3.8 Studs are to be located in the links centrally, and at right angles to the sides of the link, although the studs of the final link at each end of any length may also be located off-centre to facilitate the insertion of the joining shackle. The tolerances in accordance with Fig. 10.3.2 are acceptable provided that the stud fits snugly and its ends lie flush against the inside of the link.

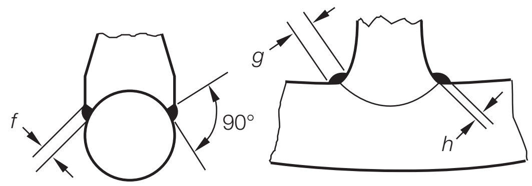
3.4 Studs

3.4.1 The studs are to be made of steel corresponding to that of the chain or in compliance with a specification approved by LR. In general, the carbon content should not exceed 0,23 per cent if the studs are to be welded in place.

3.4.2 Studs may be welded into grade R3 and R3S chains. The welding of studs into grade R4, R4S and R5 chain is not permitted unless specially approved.

3.4.3 In all cases where studs are welded into links, this is to be carried out in accordance with 2.7.

3.4.4 The size of the stud welds is to be in accordance with Fig. 10.3.1.



Dimension Designation	Nominal Dimension	Minus Tolerance
f	0,10*d*	0,01*d*
g	0,20*d*	0,02*d*
h	0,09*d*	0,01*d*

d = Nominal diameter of barstock

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Fig. 10.3.1
Dimensions and tolerances of stud welds

3.4.5 All stud welds are to be visually inspected. At least 10 per cent of all stud welds within each length of chain are to be examined by magnetic particle inspection after proof load testing. Stress raising defects such as cracks, lack of fusion, gross porosity, and undercuts exceeding 1 mm are not permitted; if any such defects are found, then all stud welds in that length of chain are to be examined by means of magnetic particle inspection.

3.4.6 Where plastic straining is used to set studs, the applied load is not to be greater than that qualified in approval tests. The combined effect of shape and depth of the impression of the stud in the link is not to cause any harmful notch effect or stress concentration.

3.5 Heat treatment of completed chain cables

3.5.1 The chain is to be normalised, normalised and tempered or quenched and tempered in accordance with the specification approved by LR.

3.5.2 The chains are to be heat treated in a continuous furnace; batch heat treatment is not permitted.

3.5.3 The temperature and time, or temperature and chain speed, are to be controlled and continuously recorded.

3.5.4 Heat treatment is to be carried out prior to the proof loading and breaking tests.

3.5.5 Calibration of furnaces is to be verified by measurement and recording of actual link temperature (surface and internal).

3.6 Testing of completed chain cables

3.6.1 All chain cables are to be tested in the presence of a Surveyor, at a proving establishment recognised by LR. A list of recognised proving establishments is published by LR. In addition to the requirements stated in this Chapter, attention must be given to any relevant statutory requirements of the National Authority of the country in which the ship is to be registered.

3.6.2 The entire length of chain cable is to be subjected to a proof loading test in an approved testing machine and is to withstand the load given in Table 10.3.1 for the appropriate grade and size of cable.

3.6.3 Care should be taken to obtain a uniform stress distribution in the links being tested.

3.6.4 The chain is to be shot or sand blasted prior to testing in order to ensure that its surfaces are free from scale, paint or other coating for inspection.

3.6.5 On completion of the proof load test, each link is to be visually examined and is to be free from significant defects such as mill defects, surface cracks, dents and cuts, especially where gripped by clamping dies during flash butt welding. Studs are to be securely fastened and any burrs, irregularities and rough edges are to be removed by careful grinding.

3.6.6 All flash butt welds, including the area gripped by the clamping dies, are to be examined by magnetic particle inspection. The area is to be free from cracks, lack of fusion, gross porosity and any other stress concentrations.

3.6.7 Surface defects in the region of the flash butt welds may be removed by grinding, provided that the depth of grinding does not exceed five per cent of the link diameter and is smoothly contoured into the surrounding material. The final dimensions are still to conform with the agreed standard.

3.6.8 All flash butt welds are also to be examined by ultrasonic inspection and are to be free from defects such as internal cracks or lack of fusion.

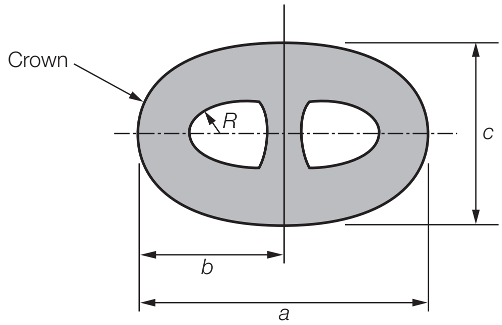
3.6.9 All non-destructive examination is to be carried out in accordance with approved procedures, in accordance with Ch 1,5.

3.6.10 All non-destructive examination operators are to be qualified to a minimum Level II, qualified in accordance with a recognised standard.

3.6.11 After proof testing, the entire chain is to be checked for length, five links at a time with an overlap of two links, which is to include the first five links, to ensure that the chain meets the tolerances given in 2.15.5. The measurements are to be made while the chain is loaded to about 10 per cent of the proof load.

Fig. 10.3.2 Stud link tolerances

The internal link radii (*R*) and external radii should be uniform



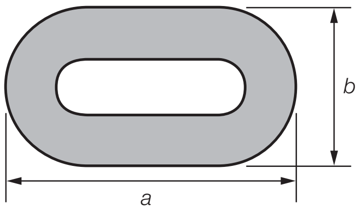
Designation	Description	Nominal dimension of the link	Minus tolerance	Plus tolerance
a	Link length	6*d*	0,15*d*	0,15*d*
b	Link half length	*a**/2	0,10*d*	0,10*d*
c	Link width	3,6*d*	0,09*d*	0,09*d*
e	Stud angular misalignment	0 degrees	4 degrees	4 degrees
R	Inner radius	0,65*d*	0	—

Symbols

d = nominal diameter of chain
*a** = actual link length

Fig. 10.3.3 Studless and common link tolerances

The internal link radii (*R*) and external radii should be uniform



Designation	Description	Nominal dimension of the link	Minus tolerance	Plus tolerance
a	Link length	6*d*	0,15*d*	0,15*d*
b	Link width	3,35*d*	0,09*d*	0,09*d*
R	Inner radius	0,60*d*	0	—

Symbols

d = nominal diameter of chain

NOTE
Other dimensional ratios are subject to special approval.

Table 10.3.1 Test loads for mooring chain cables *(continued)*

Nominal diameter *d*	Grade R3			Grade R3S			Grade R4			Grade R4S			Grade R5		
	Proof test load		Break test load	Proof test load		Break test load	Proof test load		Break test load	Proof test load		Break test load	Proof test load		Break test load
	Stud link chain	Studless chain		Stud link chain	Studless chain		Stud link chain	Studless chain		Stud link chain	Studless chain		Stud link chain	Studless chain	
mm	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN
50	1480	1480	2230	1800	1740	2490	2160	1920	2740	2400	2130	3040	2510	2230	3200
52	1594	1594	2402	1939	1874	2682	2327	2068	2952	2585	2295	3275	2704	2402	3447
54	1712	1712	2580	2083	2013	2881	2499	2222	3170	2777	2465	3517	2904	2580	3703
56	1834	1834	2764	2231	2156	3086	2677	2380	3396	2974	2640	3768	3111	2764	3966
58	1960	1960	2953	2383	2304	3297	2860	2542	3628	3178	2820	4025	3323	2953	4237
60	2089	2089	3147	2540	2455	3514	3048	2710	3867	3387	3006	4290	3542	3147	4516
62	2221	2221	3347	2701	2611	3737	3242	2881	4112	3602	3196	4562	3767	3347	4802
64	2357	2357	3551	2867	2771	3965	3440	3058	4364	3822	3392	4841	3997	3551	5096
66	2496	2496	3761	3036	2935	4200	3643	3238	4621	4048	3593	5127	4233	3761	5397
68	2639	2639	3976	3209	3102	4440	3851	3423	4885	4279	3798	5420	4475	3976	5706
70	2785	2785	4196	3387	3274	4685	4064	3613	5156	4516	4008	5720	4723	4196	6021
73	3010	3010	4535	3660	3538	5064	4392	3904	5572	4881	4331	6182	5104	4535	6507
76	3242	3242	4884	3942	3811	5454	4731	4205	6001	5257	4665	6658	5498	4884	7009
78	3400	3400	5123	4135	3997	5720	4962	4411	6295	5514	4893	6984	5766	5123	7351
81	3643	3643	5490	4431	4283	6130	5317	4726	6745	5908	5243	7484	6179	5490	7877
84	3893	3893	5866	4735	4577	6550	5682	5051	7208	6313	5603	7997	6602	5866	8418
87	4149	4149	6252	5046	4878	6981	6056	5383	7682	6729	5972	8523	7037	6252	8971
90	4412	4412	6647	5365	5187	7422	6439	5723	8167	7154	6349	9062	7482	6647	9539
92	4590	4590	6916	5582	5396	7722	6699	5954	8497	7443	6606	9428	7784	6916	9924
95	4862	4862	7326	5913	5716	8180	7096	6307	9001	7884	6997	9987	8246	7326	10512
97	5047	5047	7604	6138	5933	8490	7365	6547	9343	8184	7263	10366	8559	7604	10911
100	5328	5328	8028	6480	6264	8964	7776	6912	9864	8640	7668	10944	9036	8028	11520
102	5519	5519	8315	6712	6488	9285	8054	7159	10217	8949	7942	11336	9359	8315	11932
105	5809	5809	8753	7065	6829	9773	8478	7536	10754	9420	8360	11932	9851	8753	12560
107	6005	6005	9048	7304	7060	10103	8764	7790	11118	9738	8643	12335	10184	9048	12984
111	6404	6404	9650	7789	7529	10775	9347	8308	11856	10385	9217	13154	10861	9650	13847
114	6709	6709	10109	8159	7887	11287	9791	8703	12420	10879	9655	13780	11378	10109	14506
117	7018	7018	10574	8535	8251	11807	10242	9104	12993	11380	10100	14415	11902	10574	15174
120	7331	7331	11047	8916	8619	12334	10700	9511	13573	11889	10551	15059	12434	11047	15852
122	7542	7542	11365	9173	8868	12690	11008	9785	13964	12231	10855	15493	12792	11365	16308
124	7755	7755	11686	9432	9118	13048	11319	10061	14358	12576	11161	15930	13153	11686	16768
127	8078	8078	12171	9824	9497	13591	11789	10479	14955	13099	11626	16592	13700	12171	17466
130	8404	8404	12663	10221	9880	14139	12265	10903	15559	13628	12095	17262	14253	12663	18171
132	8623	8623	12993	10488	10138	14508	12585	11187	15965	13984	12411	17713	14625	12993	18645
137	9178	9178	13829	11162	10790	15441	13395	11906	16992	14883	13209	18852	15565	13829	19844

Table 10.3.1 **Test loads for mooring chain cables** *(conclusion)*

Nominal diameter d	Grade R3			Grade R3S			Grade R4			Grade R4S			Grade R5		
	Proof test load		Break test load	Proof test load		Break test load	Proof test load		Break test load	Proof test load		Break test load	Proof test load		Break test load
	Stud link chain	Studless chain		Stud link chain	Studless chain		Stud link chain	Studless chain		Stud link chain	Studless chain		Stud link chain	Studless chain	
mm	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN
142	9741	9741	14677	11847	11452	16388	14216	12637	18033	15796	14019	20008	16520	14677	21061
147	10311	10311	15536	12540	12122	17347	15048	13376	19089	16720	14839	21179	17487	15536	22294
152	10887	10887	16405	13241	12800	18317	15890	14124	20156	17655	15669	22363	18464	16405	23540
157	11469	11469	17282	13949	13484	19297	16739	14879	21234	18599	16507	23559	19452	17282	24799
162	12056	12056	18166	14663	14174	20284	17596	15641	22320	19551	17351	24764	20447	18166	26068
167	12647	12647	19056	15381	14869	21278	18458	16407	23414	20508	18201	25977	21448	19056	27345
172	13240	13240	19950	16103	15566	22276	19324	17177	24513	21471	19055	27196	22455	19950	28628
177	13836	13836	20847	16827	16267	23278	20193	17949	25615	22437	19912	28420	23465	20847	29915
182	14433	14433	21746	17553	16968	24282	21064	18723	26720	23404	20771	29645	24477	21746	31205
187	15029	15029	22646	18279	17670	25286	21935	19498	27825	24372	21630	30871	25489	22646	32496
192	15626	15626	23544	19004	18371	26289	22805	20271	28929	25339	22488	32096	26500	23544	33785
197	16220	16220	24440	19727	19070	27290	23673	21043	30029	26303	23344	33317	27509	24440	35071
202	16813	16813	25332	20448	19766	28286	24537	21811	31126	27264	24196	34534	28513	25332	36351
207	17401	17401	26220	21164	20459	29277	25397	22575	32216	28219	25044	35744	29512	26220	37625
210	17753	17753	26749	21591	20872	29868	25910	23031	32867	28788	25550	36465	30108	26749	38385

Grade R3		
Proof test load	Stud link chain	$0{,}0148d^2\,(44 - 0{,}08d)$
	Studless chain	$0{,}0148d^2\,(44 - 0{,}08d)$
Break test load		$0{,}0223d^2\,(44 - 0{,}08d)$
Grade R3S		
Proof test load	Stud link chain	$0.0180d^2\,(44 - 0{,}08d)$
	Studless chain	$0{,}0174d^2\,(44 - 0{,}08d)$
Break test load		$0{,}0249d^2\,(44 - 0{,}08d)$
Grade R4		
Proof test load	Stud link chain	$0{,}0216d^2\,(44 - 0{,}08d)$
	Studless chain	$0{,}0192d^2\,(44 - 0{,}08d)$
Break test load		$0{,}0274d^2\,(44 - 0{,}08d)$
Grade R4S		
Proof test load	Stud link chain	$0{,}0240d^2\,(44 - 0{,}08d)$
	Studless chain	$0{,}0213d^2\,(44 - 0{,}08d)$
Break test load		$0{,}0304d^2\,(44 - 0{,}08d)$
Grade R5		
Proof test load	Stud link chain	$0{,}0251d^2\,(44 - 0{,}08d)$
	Studless chain	$0{,}0223d^2\,(44 - 0{,}08d)$
Break test load		$0{,}0320d^2\,(44 - 0{,}08d)$

3.6.12 The links held in the end blocks may be excluded from these measurements.

3.6.13 If the length over five links is less than the nominal, the chain may be stretched by loading above the specified proof test load provided that the applied load is not greater than ten per cent above the proof test load, and that only random lengths of the chain need to be stretched.

3.6.14 Loads used for plastic straining to set studs are not to exceed those approved in qualification tests.

3.6.15 Checks of all other dimensions are to be made on at least five per cent of the links in the cable.

3.6.16 If any link fails to meet the dimensional tolerance requirements (*see* 3.3), measurements are to be made on 20 more links on each side of the incorrect one. If failure to meet any particular dimensional requirements occurs in more than two of the measured links, then all the links are to be dimensionally checked.

3.6.17 Should any link be found to be defective or fail to meet the dimensional tolerance requirements or if a five link length of chain exceeds the specified tolerance, the unsatisfactory links are to be removed from the chain, and connecting common links complying with the requirements of 3.7 inserted in their places.

3.6.18 The chain is then to be subjected to a further proof load test and re-examined.

3.6.19 The number of connecting common links which may be used to replace defective links is not to exceed three in any 100 m length of chain. The number and type of joining shackles which may be used are to be subject to the written agreement of the end user.

3.6.20 If a link breaks during proof load testing, a sample consisting of three common links is to be taken from each side of the broken link and subjected to a breaking test as detailed in 3.6.21 and 3.6.22. If either of these samples fails, the proof loaded length of cable is not to be accepted. A thorough examination of all broken links is to be made to determine the cause of failure and, after evaluation, LR will consider the extent of cable which is to be rejected and also the possibility that similar factors to those which caused the failure may also be present in other parts of the cable, or other chain cables. The Surveyor is to be advised in advance of all examinations, with reasonable notice being given.

3.6.21 In addition to the requirements of 3.6.2, three link samples are to be selected by the Surveyors from the completed chain for breaking tests. The number of tests required is to be in accordance with Table 10.3.2. Extra links are to be provided for the mechanical tests detailed in 3.6.25. All test links are to be made as part of the chain cable and are to be heat treated with it. These may be removed from the cable prior to heat treatment provided that each sample is heat treated with, and in the same manner as, the chain it represents prior to selection of the mechanical test specimens. They are to be properly identified with the length of chain they represent.

Table 10.3.2 Frequency of break and mechanical tests

Nominal chain diameter mm	Maximum sampling interval m (*See* Note)
Min. — 48	91
49 — 60	110
61 — 73	131
74 — 85	152
86 — 98	175
99 — 111	198
112 — 124	222
125 — 137	250
138 — 149	274
150 — 162	297
163 — 175	322
176 — 186	346
187 — 199	370
199 — 210	395

NOTE
If the sampling interval contains links made from more than one cast, extra break and mechanical tests are required so that tests are made on every cast.

3.6.22 Breaking test specimens are to withstand the load given in Table 10.3.1 for the appropriate grade and size of cable for a period of 30 seconds. The specimen is considered to have passed this test if it has shown no sign of fracture after application of the required load.

3.6.23 If a breaking test specimen fails, two further specimens are to be cut from the same sampling length and both are to be subjected to the breaking test load. If one of the re-test specimens fails the length is to be rejected. All the broken links are to be subjected to an investigation into the cause of failure. LR will then decide which lengths of chain can be accepted and on further action.

3.6.24 For large diameter cables where the required breaking load is greater than the capacity of the testing machines, special consideration will be given to acceptance of an alternative testing procedure.

3.6.25 One tensile and three sets of Charpy V-notch impact test specimens are to be taken from links cut from the heat treated and proof loaded chain at intervals no greater than those indicated in Table 10.3.2 provided that every cast is sampled. The tensile specimen and one set of impact specimens are to be taken from the side of the link opposite the weld. One set of impact test specimens is to have the notches positioned at the centre of the flash butt weld and the third set is to be taken from the bend. All the specimens are to be taken from positions in accordance with Fig. 10.3.4.

3.6.26 The frequency of testing at the link bends may be reduced at the discretion of LR provided it can be verified that the required toughness is achieved consistently.

3.6.27 The results of the mechanical tests are to comply with the requirements of Table 10.3.3.

Table 10.3.3 Mechanical properties of chain cable materials

Grade	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation % minimum	Reduction of area % minimum (*See* Note 3)	Charpy V-notch impact tests: Test temperature °C	Charpy V-notch impact tests: Average energy J minimum	Charpy V-notch impact tests: Average energy flash weld J minimum
R3	410 (*See* Note 1)	690 minimum (*See* Note 1)	17	50	0 –20 (*See* Note 2)	60 40	50 30
R3S	490 (*See* Note 1)	770 minimum (*See* Note 1)	15	50	0 –20 (*See* Note 2)	65 45	53 33
R4	580 (*See* Note 1)	860 minimum (*See* Note 1)	12	50	–20	50	36
R4S (*See* Note 4)	700 (*See* Note 1)	960 (*See* Note 1)	12	50	–20	56	40
R5 (*See* Note 4)	760 (*See* Note 1)	1000 (*See* Note 1)	12	50	–20	58	42

NOTES
1. The ratio of yield strength to tensile strength should not exceed 0,92.
2. Testing may be carried out at either 0°C or –20°C.
3. For cast fittings, the minimum values for reduction of area are to be 40% for Grades R3 and R3S and 35% for Grades R4, R4S and R5.
4. The maximum hardness for Grade R4S is to be HB330, and for Grade R5 is to be HB340.

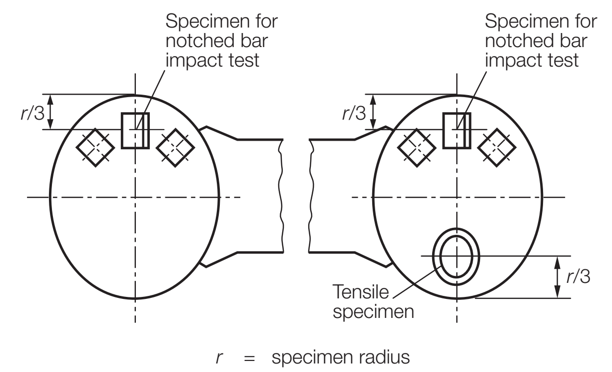


Fig. 10.3.4 Sampling of chain links

3.6.28 If the tensile test requirements are not achieved, two further specimens from the same sample are to be tested. The related length of chain will be considered acceptable if both re-test specimens meet the requirements but failure of either of the re-test specimens will result in rejection of the sampling length of chain represented by the tests.

3.6.29 If the impact test requirements are not achieved, re-tests may be carried out in accordance with Ch 1,2.4. Failure to meet the re-test requirements will result in rejection of the sampling length of chain represented by the tests.

3.6.30 The mass per unit length of stud link mooring cable is to comply with Table 10.3.4.

Table 10.3.4 Mass per unit length of chain cable

Nominal chain diameter (mm)	Mass per unit length $0{,}0291d^2$ (kg/m)
50	73
55	88
60	105
65	123
70	143
75	164
80	186
85	210
90	236
95	263
100	291
105	321
110	352
115	385
120	419
125	455
130	492
135	530
140	570
145	612
150	655
155	699
160	745
165	792
170	841
175	891
180	943
185	996
190	1051
195	1107
200	1164
205	1223
210	1283

3.7 Connecting common links or substitute links

3.7.1 Single links to connect lengths of heat treated chain cable or to substitute for test links or defective links without the necessity for re-heat treatment of the whole length of cable are to be made by the chain manufacturer in accordance with an approved procedure. Separate approvals are required for each grade of chain cable and tests are to be made on the maximum size of chain for which approval is sought.

3.7.2 Manufacture and heat treatment of the connecting common link is not to affect the strength of the adjoining links. The temperature reached by these links is nowhere to exceed 250°C.

3.7.3 The steel bar used is to conform with the specification for the chain and approved by LR in accordance with Ch 3,9.

3.7.4 Details of the method of manufacture, including heat treatment, are to be submitted for approval, together with the results of a series of tests laid down by LR.

3.7.5 All links involved in the approval tests are to be destroyed and are not to be used as part of a chain cable.

3.7.6 Every connecting common link included in a chain cable is to be subjected to the proof load appropriate to the grade and size of chain in which it is incorporated as detailed in Table 10.3.1.

3.7.7 Every connecting common link is to be inspected in accordance with 3.6.5 to 3.6.10.

3.7.8 A second identical link is to be made for mechanical tests which are to be in accordance with 3.6.25. This test link is also to be inspected in accordance with 3.7.7.

3.7.9 Each connecting common link is to be stamped on the stud with the identification marks listed in 3.9.1 plus a unique number for the link. The adjoining links are also to be stamped on the studs.

3.8 Fittings for offshore mooring chain

3.8.1 Cable fittings are to be manufactured at an approved works. Fittings include, but are not limited to, shackles, triplates, end shackles, swivels, and swivel shackles.

3.8.2 The materials from which the fittings are made are to be manufactured at approved works, in accordance with the appropriate requirements of Ch 4,1 or Ch 5,1, and 3.8.3 to 3.8.6. Alternative arrangements may be agreed provided that full details concerning the manufacturer are submitted to LR.

3.8.3 Steel used for fittings must be manufactured by an approved process, and be killed and fine grain treated.

3.8.4 The austenite grain size of steel used for fittings must be 6 or finer as measured in accordance with ASTM E112.

3.8.5 Steel used for forgings or castings for grades R4S and R5 must be vacuum degassed.

3.8.6 For steel used for forgings or castings for grades R4S and R5 the following tests are to be carried out on each heat:

(a) Assessment and quantification of the level of non-metallic micro inclusions. These must be acceptable for the final product.
(b) Macro etching on representative sample, in accordance with ASTM E381 or equivalent, this must be free from any injurious segregation or porosity.
(c) Jominy hardenability tests in accordance with ASTM A255 or equivalent.

The results of these tests are to be supplied by the steel manufacturer, and the results are to be included in the final accessory documentation.

3.8.7 Fittings for chain are to be heat treated in accordance with procedures that have been approved by LR.

3.8.8 All fittings are to be manufactured to a manufacturing specification approved by LR, and provision is to be made for tensile and impact test specimens. The test samples are to be subjected to heat treatment with the fittings they represent. The mechanical test requirements are the same as those for the relevant grade of chain cable, *see* Table 10.3.3.

3.8.9 For fittings for mooring chain, a batch is defined as fittings from the same steel-making heat that have been heat treated together in the same furnace.

3.8.10 Mechanical tests for fittings are to be taken from full size fittings that have been heat treated with the production batch they represent, and the tests are to be taken after the fitting has been proof load tested. It is not permitted to use separate representative coupons unless approved by LR in accordance with 3.8.14.

3.8.11 Forged shackle bodies and forged Kenter shackles are to have a set of three Charpy impact tests and a tensile test taken from the crown of the shackle. For smaller diameter shackles, where the geometry does not allow for the tensile test to be taken from the crown, this may be taken from the straight portion from the locations specified in Fig. 10.3.5, with the Charpy impact test specimens on the outside radius.

3.8.12 The test pieces for cast shackle bodies and cast Kenter shackles can be taken from the straight portion of the fitting from the locations shown in Fig. 10.3.5.

3.8.13 For fittings with complex geometries the locations of test pieces taken are to be approved by LR.

3.8.14 Where fittings are produced in small batches (less than 5) alternative testing may be approved; a proposal must be submitted in a written procedure for consideration.

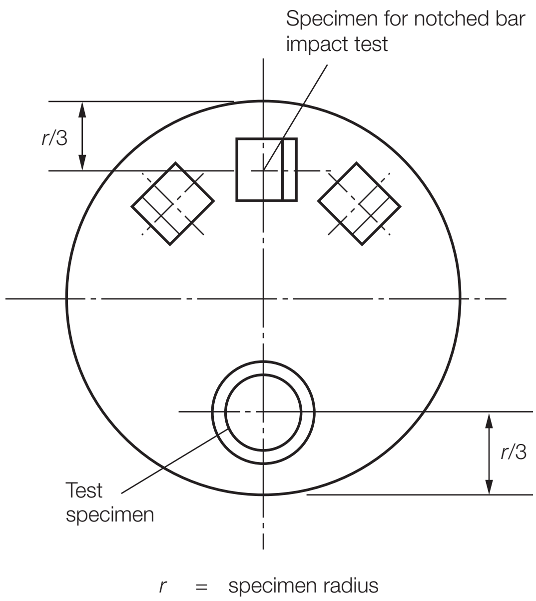


Fig. 10.3.5
Sampling of steel bars, forgings and castings

3.8.15 Mechanical tests of pins are to be taken as shown in Fig. 10.3.6 from the mid length of a sacrificial pin of the same diameter as the final pin. For oval pins, the diameter taken is to represent the smaller dimension. Mechanical tests may be taken from an extended pin of the same diameter as the final pin that incorporates a test prolongation and a heat treatment buffer prolongation, where equivalence with mid length test values have been established. The length of the buffer is to be at least equal to 1 pin diameter which is removed after the heat treatment cycle is finished. The test coupon can then be removed from the pin. The buffer and test are to come from the same end of the pin, as shown in Fig. 10.3.6.

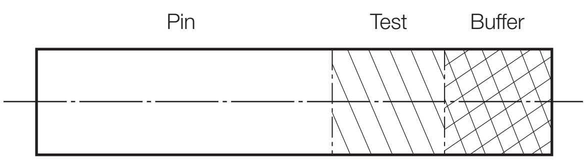


Fig. 10.3.6
Buffer and test piece location for pins

3.8.16 Manufacturers intending to supply accessories in the machined condition (e.g. Kenter type shackles) are to submit detailed drawings for approval by LR.

3.8.17 All chain cable accessories, including spares, are to be subjected to the proof loads appropriate to the grade and size of cable for which they are intended, *see* Table 10.3.1. Prior to this test, the accessories are to be shot or sand blasted to ensure that their surfaces are free from scale, paint or any other coating which could interfere with any subsequent inspection.

3.8.18 The appropriate breaking load as required by Table 10.3.1 is to be applied to at least one item out of every batch of up to 25, and this item is to be destroyed and not used as part of an outfit.

3.8.19 If the sample fails to withstand the breaking load without fracture, or in the event of failure of any other test, then the entire batch is to be rejected unless the cause of failure has been determined and it can be demonstrated that the condition causing failure is not present in any of the other accessories in the batch. If this can be demonstrated then two more samples from the same batch may be tested. If either of these samples fails, the batch is to be rejected.

3.8.20 For very large fittings where the required breaking load is greater than the capacity of the testing machine and for individually produced accessories or accessories produced in small batches, proposals for an alternative method of testing will be given special consideration. All proposals for alternative testing methods are to be detailed in writing and submitted.

3.8.21 At least one accessory from each batch is to be checked dimensionally after proof load testing. The manufacturer is to provide a statement that the dimensions comply with the specified requirements.

3.8.22 The following tolerances apply of the unmachined dimensions of all fittings;
(a) nominal diameter plus 5 per cent, minus 0 per cent; and
(b) other dimensions plus or minus 2,5 per cent.

3.8.23 All accessories are to be subjected to close visual examination after proof load testing, particular attention being paid to machined surfaces and highly stressed regions. All accessories are also to be examined by magnetic particle or dye penetrant inspection and ultrasonic testing. All NDE is to be carried out in accordance with 3.6.9 and 3.6.10. The manufacturer is to provide a statement that the non-destructive examination has been carried out with satisfactory results; this statement is to include reference to the techniques used and the operator's qualifications.

3.8.24 All testing is to be carried out to the satisfaction and in the presence of the Surveyor.

3.8.25 Fittings of increased dimensions or higher grade material may be used subject to approval by LR.

3.8.26 Where fittings with increased dimensions, or fittings of a higher material grade are included in an outfit:

(a) each item must be successfully tested at the required breaking load for the chain cable for which it is intended; and

(b) items of increased dimensions are so designed that their breaking strength is not less than 1,4 times the Rule minimum breaking load for the chain cable for which they are intended, and this has been verified by procedure tests.

3.9 Identification

3.9.1 Each length of chain is to be permanently marked with the following:

(a) LR and abbreviated name of LR's local office issuing the certificate.

(b) Certificate number (this may be abbreviated provided it is stated in the certificate).

(c) Grade and proof load of chain.

3.9.2 The chain is to be marked as follows:

(a) at each end (the marking should identify the leading and tail end of each chain),

(b) at intervals not exceeding 100 m,

(c) on all connecting common links or shackles and the immediately adjacent links,

(d) on the first and last common link of each individual heat used in the continuous length.

3.9.3 All identification marks are to be made on the studs and are to be permanent and legible throughout the expected service life of the chain.

3.10 Documentation

3.10.1 A complete Chain Inspection and Testing Report, in booklet form, is to be provided by the chain manufacturer for each continuous chain length, and for each order for chain and fittings. It is to include all dimensional checks, test and inspection reports, non-destructive test reports, process records, as well as any non-conformity, together with corrective action and repair work.

3.10.2 All documents, including reports and appendices, are to contain a reference to the relevant certificate number.

3.10.3 The chain manufacturer is responsible for storing all the documentation in a safe and retrievable manner for a period of at least 10 years.

3.11 Certification

3.11.1 An LR certificate is to be issued for each continuous single length of chain, and each type of fitting, *see* Ch 1,3.1.

3.11.2 Each test certificate is to include the following particulars:

(a) Purchaser's name and order number.

(b) Description and dimensions.

(c) Grade of chain cable.

(d) Identification mark which will enable the full history of the chain to be traced.

(e) Chemical composition.

(f) Details of heat treatment.

(g) Mechanical test results.

(h) Breaking test load.

(j) Proof load.

(k) The number and locations of all connecting common links and all marked links.

■ *Section 4* Studless mooring chain cables

4.1 Scope

4.1.1 Provision is made in this Section for five grades, R3, R3S, R4, R4S and R5 of studless flash butt welded chain cable intended for long term mooring applications.

4.1.2 The chain is generally expected to be deployed only once for a pre-determined service life.

4.1.3 Each studless chain link design will require to be approved by LR. The plan submitted for this approval is to include the minimum proof and breaking test loads, and the chain mass calculations.

4.2 Manufacture

4.2.1 All the requirements of 3.2, with the exception of that relating to studs, apply to the manufacture of studless mooring chain cables.

4.3 Shape and dimensions of links

4.3.1 The shape and dimensions of the links are to be in accordance with the approved design.

4.4 Dimensional tolerances

4.4.1 The dimensional tolerances of studless links are to be in accordance with the requirements of 3.3.1 to 3.3.7.

4.5 Heat treatment

4.5.1 Heat treatment of the chain is to be in accordance with the requirements of 3.5.

4.6 Testing of completed chain

4.6.1 All chain cables are to be tested in the presence of a Surveyor, at a proving establishment recognised by LR. A list of recognised proving establishments is published by LR. In addition to the requirements stated in this Chapter, attention must be given to any relevant statutory requirements of the National Authority of the country in which the ship is to be registered.

4.6.2 The entire length of chain cable is to be subjected to a proof load test in an approved testing machine and is to withstand the load given in Table 10.3.1 for the appropriate grade and diameter of the chain, *see also* 4.1.3.

4.6.3 Inspection after proof load testing is to be in accordance with the requirements given in 3.6.3 to 3.6.20, excluding that related to checking of studs in 3.6.5.

4.6.4 In addition to the inspection of the flash butt welded areas as required in 3.6.6, the surfaces of the bends of at least 10 per cent of the links are to be examined by magnetic particle inspection and are to be free from cracks or other defects.

4.6.5 If stretching of links is required in order to maintain dimensional tolerances, the load applied is not to exceed the proof load by more than 10 per cent, and only random lengths of the chain need to be stretched.

4.6.6 Breaking load tests are to be carried out in accordance with 3.6.21 to 3.6.23 and Tables 10.3.1 and 10.3.2.

4.6.7 Alternative procedures to breaking load testing (*see* 3.6.24) are not permissible unless prior agreement is given by LR after special consideration.

4.6.8 Mechanical testing is to be carried out in accordance with 3.6.25 to 3.6.30 and Table 3.3.4.

4.6.9 The weight of the chain cable is to be in accordance with the approved plan.

4.7 Connecting or substitute links

4.7.1 Connecting links and substitute links are to be in accordance with the requirements of 3.7.

4.8 Fittings

4.8.1 Fittings for studless chain are to comply with the requirements of 3.8.

4.9 Identification

4.9.1 All chain and each fitting is to be identified in accordance with 3.9.1 and 3.9.2.

4.9.2 Identification marks are to be made on the outside of the straight part of the link, opposite the flash butt weld.

4.10 Certification

4.10.1 Certificates are to be issued in accordance with 3.11.

4.11 Documentation

4.11.1 Documentation in accordance with 3.11 is to be provided by the manufacturer.

■ *Section 5*
Short link chain cables

5.1 Scope

5.1.1 This Section gives the requirements for electrically welded steel short link chain cable for marine use but excluding those applications covered by the *Code for Lifting Appliances in a Marine Environment*.

5.1.2 Provision is made for grade M(4), as defined in ISO 1834.

5.2 Manufacture

5.2.1 Short link chain cables are to be manufactured at works approved by LR. A list of approved manufacturers for short link chain cable is published separately by LR.

5.2.2 The chain is to be supplied in either the normalised or quenched and tempered condition. Heat treatment is to be carried out prior to proof and breaking load testing.

5.2.3 The chain may be galvanised using a hot dipping process provided that this is carried out prior to proof and breaking load testing. If galvanised, it is recommended that the thickness of the zinc coating be not less than 70 microns.

5.2.4 Unless otherwise agreed, the finished chain is to be free from coatings other than zinc.

5.3 Bar material

5.3.1 Bars for the manufacture of short link chain cable are to be made and tested in accordance with the appropriate requirements of Ch 3,1 and to the requirements of an International or acceptable National Standard.

5.3.2 The bars are to be made at a works approved by LR.

5.3.3 The steel is to be fully killed and fine grain treated.

5.3.4 The steel is to have mechanical properties which will allow the chain to meet the mechanical test requirements of 5.4.7 and Table 10.5.1.

Table 10.5.1 Mechanical test requirements for short link chain cables

Chain diameter mm	Grade M(4)	
	Proof load kN	Breaking load minimum kN
5	7,9	15,8
6,3	12,5	25
7,1	15,9	31,8
8	20,2	40,4
9	25,5	51
10	29,5	63
11,2	31,5	79
12,5	49,1	98,2
14	63	126
16	81	162
18	102	204
20	126	252
22,4	158	316
25	197	394
28	247	494
32	322	644
36	408	816
40	503	1006
45	637	1274

5.4 Testing and inspection of chain cables

5.4.1 All chain cable of 12,5 mm diameter and above, and all steering chains irrespective of diameter, are to be tested in the presence of a Surveyor at a proving establishment recognised by LR. A list of recognised proving establishments is published by LR. In addition to the requirements stated in this Chapter, attention is to be given to any relevant statutory requirements of the National Authority of the country in which the ship or other marine structure is to be registered.

5.4.2 For chain of diameter less than 12,5 mm, other than steering chains, the manufacturer's tests will be acceptable.

5.4.3 After completion of all manufacturing processes, including heat treatment and galvanising, the whole of the chain is to be subjected to the appropriate proof load specified in Table 10.5.1.

5.4.4 The whole of the chain is to be inspected after the proof load test and is to be free from significant defects.

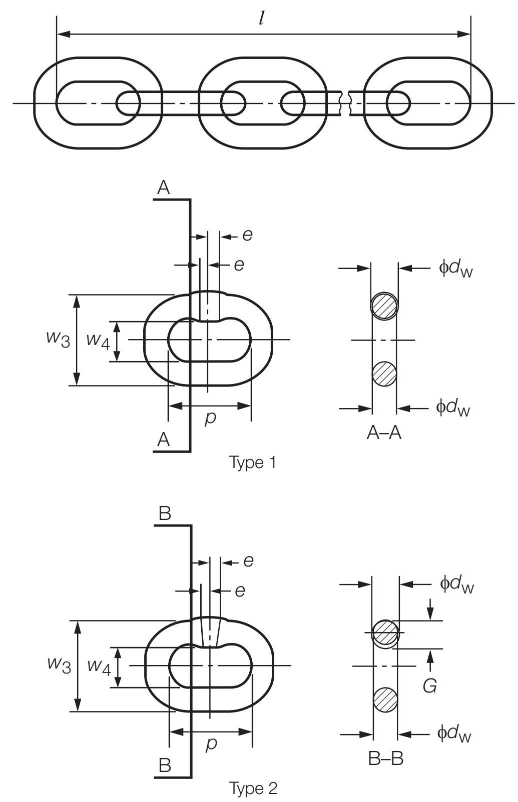
5.4.5 At least one sample, consisting of seven or more links, is to be selected by the Surveyor from each 200 m or less of chain for breaking load tests. Two additional links may be required for engagement in the jaws of the testing machine. These extra links are not to be taken into account in determining the total elongation, *see* 5.4.7.

5.4.6 The breaking load is to comply with the appropriate requirements of Table 10.5.1.

5.4.7 The total elongation of the breaking load sample at fracture, expressed as a percentage of the original inside length of the sample after proof loading, is to be not less than 20 per cent.

5.5 Dimensions and tolerances

5.5.1 The form and proportions of links are to be in accordance with Fig. 10.5.1.



l = multiple pitch length
p = pitch (internal link length)
d_n = measured diameter of the material, except at the weld
d_w = measured diameter of the material at the weld (Type 1) or weld dimension perpendicular to the plane of the link (Type 2)
G = dimension in other planes as per individual chain specification (Type 2)
e = length affected by welding, on either side of the centre link
w_1 = internal link width away from the weld
w_2 = external link width away from the weld
w_3 = external link width over the weld
w_4 = internal link width at the weld

Fig. 10.5.1 Form and proportions of links

5.5.2 Manufacturing tolerances are to be within the following limits:

Nominal diameter, d_n	± 5%
Pitch of chain, p_1	± 3%
Length measured over 11 links, l	± 2%
Inside width, w_1	1,35d_n minimum
Outside width, w	3,6d_n maximum

The tolerances are to apply after galvanising. All measurements are to be taken after proof testing.

5.6 Identification

5.6.1 All lengths of cable are to be stamped with the following identification marks:

(a) Inspector's mark and date.
(b) Reference mark or number of certificate.
(c) Manufacturer's mark or name.
(d) Chain cable quality mark, M, is to be stamped on at least each twentieth link or at intervals of one metre, whichever is the lesser distance.

5.6.2 Where the inspection is performed under LR's supervision, the inspector's mark and date are to be replaced by LR and the abbreviated name of LR's local office issuing the certificate.

5.7 Certification

5.7.1 The manufacturer is to supply the Surveyor with a certificate stating compliance with an appropriate ISO standard, and also, in the event of the requirements of 5.4 being undertaken other than in the presence of the Surveyor, stating that the test and inspection requirements have been complied with at a recognised proving establishment.

5.7.2 Each test certificate is to include the following particulars:

(a) the quality and description of chain,
(b) identification mark,
(c) nominal size of chain,
(d) proof load,
(e) breaking load,
(f) total elongation at fracture,
(g) where appropriate, the name of the proving establishment.

■ *Section 6* Steel wire ropes

6.1 Scope

6.1.1 Provision is made in this Section for the requirements for the manufacture, testing and certification of steel wire ropes intended to be used for general marine purposes, as well as permanent anchoring, mooring and marine lifting applications.

6.2 General requirements

6.2.1 For general marine purposes, such as stream wires, towlines and ship mooring lines, the construction is to be in accordance with Table 10.6.1. The construction, diameter and strength of steel wire ropes for permanent offshore applications, such as mooring, anchoring and lifting, are covered by other LR Rules. Alternative applications of wire ropes may be accepted, subject to special consideration.

6.2.2 The manufacturer's plant and method of production are to be approved by LR. A list of approved manufacturers of steel wire ropes is published annually in the *List of Approved Manufacturers of Materials*.

6.2.3 For shaped wire, for example, for large diameter ropes for permanent mooring, where there are no established Standards, the manufacturer is to provide evidence by way of test reports that specifications have been developed and agreed with the purchaser and LR for the purposes intended.

6.3 Steel wire for ropes

6.3.1 Steel wire is to be of homogeneous quality, uniform strength and free of defects likely to impair the manufacture and performance of the rope.

6.3.2 For all ropes, the specified minimum tensile strength of the wire is to be 1420, 1570, 1770 or 1960 N/mm^2. The specified minimum tensile strength of the wire is the designated grade for the rope, unless otherwise defined by the purchaser's specification. The actual tensile strength of the wire is not to exceed 120 per cent of the specified minimum tensile strength.

Table 10.6.1 Recommended rope construction

Purpose	Construction of rope			Construction of strands
	Strands	Wires	Core	
Stream wires, towlines and mooring lines	6	24	Fibre	15 over 9 over fibre core
	6	37	Fibre	18 over 12 over 6 over 1
	6	26	Fibre	10 over (5 + 5) over 5 over 1
	6	31	Fibre	12 over (6 + 6) over 6 over 1
	6	36	Fibre	14 over (7 + 7) over 7 over 1
	6	41	Fibre	16 over (8 + 8) over 8 over 1
	6	30	Fibre	18 over 12 over fibre core
Towlines and mooring lines used in association with mooring winches	6	31	7 x 7 wire rope	12 over (6 + 6) over 6 over 1
	6	36	7 x 7 wire rope	14 over (7 + 7) over 7 over 1
	6	41	7 x 7 wire rope	16 over (8 + 8) over 8 over 1

6.3.3 For new rope construction, the manufacturer is to carry out prototype testing suitable for the application of the rope and this is to include tests on wire used for the construction.

6.3.4 Tensile and torsion tests, coating, and adhesion (wrap) tests are to be carried out on wire used for the manufacture of rope.

6.3.5 At least 10 per cent of the spools used for the manufacture of the strand are to be tested. The manufacturer is to demonstrate that tests have been carried out on at least one wire intended for each of the outer and inner strands, and for each diameter and grade used.

6.3.6 The heat number, wire diameter and strength of wire used for a particular construction are to be recorded by the manufacturer.

6.3.7 Torsion tests are to be carried out on the wire by causing one or both of the securing vices to be revolved until fracture occurs (a tensile load not exceeding two per cent of the breaking load of the wire may be applied to keep the wire stretched).

6.3.8 The uncoated wire is to withstand, without fracture, the number of complete twists given for Grades 1 or 3 in Table 10.6.2.

6.3.9 The galvanised wire is to withstand, without fracture, the number of complete twists given in the specification, as agreed with the purchaser and LR. In the absence of a suitable specification, the results are to comply with Table 10.6.2.

Table 10.6.2 Torsion test

Diameter coated wire mm	Minimum number of twists					
	Grade 2		Grade 1 or 3			
	Minimum strength N/mm^2		Minimum strength N/mm^2			
	1570	1770	1420	1570	1770	1960
<1,3	19	18	29	26	23	23
≥1,3 <2,3	18	17	26	24	21	21
≥2,3 <3,0	16	14	24	22	—	19
≥3,0 <4,0	12	10	20	18	—	17
≥4,0 <4,6	—	—	18	16	—	—
≥4,6 <5,0	—	—	16	14	—	—
≥5,0 <6,0	—	—	14	11	—	—

NOTE
The minimum test length is 100*d* or 300 mm, where *d* is the wire diameter.

6.3.10 Hot dipped galvanised steel wire is to be used for the manufacture of ropes for marine applications. Depending upon the application, the coating may comply with any of the grades in Table 10.6.3. Grades 1 and 2 are heavy coatings. Grade 3 is the minimum coating weight where the galvanising is carried out prior to final wire drawing. Uncoated wire may be considered for approved applications.

Table 10.6.3 Zinc coating

Diameter of coated wire mm	Zinc coating, minimum g/m^2		
	Grade1	Grade 2	Grade 3
≥0,20 <0,25	—	30	20
≥0,25 <0,33	—	45	30
≥0,33 <0,40	—	60	30
≥0,40 <0,50	60	75	40
≥0,50 <0,60	70	90	50
≥0,60 <0,80	85	110	60
≥0,80 <1,00	95	130	70
≥1,00 <1,20	110	150	80
≥1,20 <1,50	120	165	90
≥1,50 <1,90	130	180	100
≥1,90 <2,50	—	205	110
≥2,50 <3,20	—	230	125
≥3,20 <4,00	—	250	135

6.3.11 The mass per unit area of the zinc coating is to be determined in accordance with a recognised National or International Standard.

6.3.12 Zinc coating tests are to be carried out for each designated grade of wire. The manufacturer is to demonstrate that the coatings are continuous and uniform and suitable for the intended purpose.

6.3.13 Unless otherwise specified by the purchaser, zinc coating tests are to be carried out on the wire prior to stranding.

6.3.14 The adhesion of the coating is to be tested by wrapping the wire round a cylindrical mandrel for 10 complete turns. The ratio between the diameter of the mandrel and that of the wire is to be as in Table 10.6.4. After wrapping on the appropriate mandrel, the zinc coating is to have neither flaked nor cracked to such an extent that any zinc can be removed by rubbing with a cloth.

Table 10.6.4 Wrap test for adhesion of coating

Coating	Diameter of coated wire mm	Maximum ratio of mandrel to wire diameter
Grade 1 and 2	<1,5	4
	≥1,5	6
Grade 3	<1,5	2
	≥1,5	3

6.4 Tests on completed ropes

6.4.1 Every length of wire rope is to be subjected to a breaking strength test.

6.4.2 A sample of sufficient length is to be provided for the breaking load test. The rope ends are to be enclosed in a suitable socket. Testing is to be carried out in accordance with a recognised National or International Standard.

6.4.3 The rope may be subject to cyclic loading for bedding purposes prior to testing. The rope is to be tested at a suitable strain rate in accordance with a recognised National or International Standard.

6.4.4 The load is to be applied until one wire break is witnessed or 130 per cent of the minimum breaking load is recorded. The maximum recorded load is to be reported by the manufacturer.

6.4.5 Tests in which a breakage occurs adjacent to and as a result of damage from the grips are to be rejected, if the applied load is less than the specified minimum requirement. The rope is to be retested to withstand the agreed minimum breaking load.

6.4.6 With the exception of offshore mooring ropes, consideration may be given to determining the breaking load by summation or aggregating actual test results on individual wires, if facilities are not available for undertaking a breaking test on a production basis. A suitable spin factor or lay-up deduction allowance in accordance with a recognised National or International Standard for the applicable rope diameter, designated grade and construction is to be applied.

6.4.7 Where spin factors or lay-up deduction allowances are proposed by the manufacturer, a report on suitable cyclic load testing of prototype ropes of the same construction, strength and diameter is to be approved by LR. In addition, the manufacturer is to show that a satisfactory breaking load test has been carried out in the previous two years, and witnessed by LR for the same rope construction, diameter and designated grade.

6.4.8 LR may give special consideration to spin factors or lay deductions based on data extrapolated from smaller diameter ropes of the same construction, provided that these ropes have been tested in accordance with 6.4.7.

6.4.9 All data arising from smaller diameter ropes for the extrapolation in 6.4.8 are to have been derived from tests carried out within two years of the manufacture of the larger diameter rope.

6.4.10 The finished rope is to have no more than one wire connecting weld in any length of 18*d*, where *d* is the diameter of the rope.

6.5 Inspection

6.5.1 A report on dimensional and visual examination is to be presented to the Surveyor by the manufacturer. The dimensions and discard criteria are to comply with an agreed National or International Standard.

6.5.2 Visual and dimensional checks are to be carried out in the presence of the Surveyor.

6.6 Identification

6.6.1 All completed ropes are to be identified with attached labels detailing the rope type, diameter and length.

6.7 Certification

6.7.1 A manufacturer's certificate, in accordance with Ch1,3.1.3(c), is to be issued. The certificate is to be validated by the manufacturer's representative, who is to be independent of the production process and LR.

6.7.2 Each test certificate is to contain the following particulars:

- Purchaser's name and order number.
- Details of the rope construction.
- Core material.
- Grade of zinc coating.
- Mechanical test results.
- Adhesion test results.
- Dimensions.
- Method of breaking load testing.
- Breaking load.

■ *Section 7* Fibre ropes

7.1 Manufacture

7.1.1 Fibre ropes intended as mooring lines may be made of coir, hemp, manila or sisal, or may be composed of synthetic (man-made) fibres. They may be three-strand (hawser laid), four-strand (shroud laid) or nine-strand (cable laid), but other constructions will be specially considered.

7.1.2 Each length of rope is to be manufactured from suitable material of good and consistent quality. Rope materials should, in general, comply with a recognised National Standard.

7.1.3 Synthetic fibre ropes are to be suitable for the purpose intended and should comply with a recognised standard.

7.1.4 Weighting and loading matter is not to be added, and any lubricant is to be kept to a minimum. Any rot-proofing or water repellancy treatment is not to be deleterious to the fibre nor is it to add to the weight or reduce the strength of the rope.

7.2 Tests of completed ropes

7.2.1 The breaking load is to be determined by testing to destruction a sample cut from the completed rope.

7.2.2 The minimum test length and the initial test load are to be as given in Table 10.7.1. After application of the initial load, the diameter and evenness of lay up of the sample are to be checked. The sample is then to be uniformly strained at the rate given in Table 10.7.1 until it breaks.

7.2.3 The actual breaking load is to be not less than that given in an appropriate National Standard.

Table 10.7.1 Breaking load test

Material	Test length mm minimum	Initial load % (*see* Note)	Rate of straining mm/min
Natural fibre	1800	2	150 ± 50
Synthetic fibre	900	1	100 max.
NOTE Percentage of specified minimum breaking load.			

7.2.4 If the sample is held by grips and the break occurs within 150 mm of the grips, the test may be repeated, but not more than two tests may be made on any one coil.

7.2.5 Where difficulty is experienced in testing a sample of a completed synthetic fibre rope, LR will consider alternative methods of testing.

7.3 Identification

7.3.1 Each coil of rope is to be identified with an attached label detailing the material, construction, diameter and length.

7.4 Certification

7.4.1 A manufacturer's certificate, in accordance with Ch1,3.1.3(c), is to be issued. The certificate is to be validated by the manufacturer's representative, who is to be independent of the production process and LR.

7.4.2 Each test certificate is to include the following particulars:

- Manufacturer's name.
- Purchaser's name and order number.
- Rope type.
- Dimensions.
- Test length.
- Rate of straining.
- Breaking load.

Section

■ *Section 1* General

1.1 Scope

1.1.1 Provision is made in this Chapter for the approval by Lloyd's Register (hereinafter referred to as 'LR') of electrodes, wires, fluxes and other consumables intended for use in the welding of the following types of materials:

(a) Steel of various grades as represented by Grade A through to Grade FH69, *see* Sections 3 to 7.
(b) A wide range of low-temperature service steels, *see* Sections 3 to 7.
(c) Stainless steels including nitrogen strengthened grades and some of the duplex varieties, *see* Section 8.
(d) Aluminium alloys, *see* Section 9.

1.1.2 For this purpose, welding, consumables are categorised and subject to the special requirements of different Sections of this Chapter.

(a) Covered electrodes for manual welding and gravity welding.
(b) Combinations of wire and flux for automatic submerged-arc welding.
(c) Combinations of wire and gas for gas metal-arc welding and wires for self-shielding welding.
(d) Combinations for electro-slag and electro-gas welding.
(e) Combinations with temporary backing materials for one-side welding.
(f) Consumables for welding austenitic and duplex stainless steels.
(g) Combinations for welding aluminium.

1.2 Grading

1.2.1 Consumables for welding structural steels are graded into ten strength levels, and each of these is further subdivided into several levels in respect of notch toughness. The five basic levels of toughness are indicated by a number (1 to 5). Normal tensile strength is indicated by 'N'. Higher tensile strength is indicated by 'Y', and if the yield strength is higher than 375 N/mm^2 the Y is followed by a number (40 to 69), as shown in Table 11.1.1.

1.2.2 In addition to the grade, consumables are also allocated a suffix indicating the welding technique used. These are defined in the context of the following Sections of this Chapter.

1.2.3 Consumables for structural and low temperature service steels may be controlled low hydrogen and approved as such. Grade marking H15, H10 or H5 will be applied, as appropriate.

1.2.4 For joining higher strength steels, approval granted for 1Y consumables will be limited to maximum material thickness of 25 mm.

1.2.5 Test assemblies are not to be subjected to any heat treatment, except in those higher strength grades where it is considered necessary to use the welded joint in the stress relieved (tempered) condition. In those cases, the code 'sr' will be added to the approval grade.

1.2.6 Further details of grading are given in subsequent Sections of this Chapter.

1.3 Manufacture

1.3.1 The manufacturer's plant and method of production of welding consumables are to be such as to ensure reasonable uniformity in manufacture.

1.4 Approval procedures

1.4.1 Welding consumables will be approved subject to a satisfactory inspection of the works by the Surveyor for compliance with the test requirements detailed in subsequent Sections in this Chapter.

1.4.2 The test assemblies are to be prepared under the supervision of the Surveyor, and using samples selected by him. All tests are to be carried out in his presence.

1.4.3 For Charpy V-notch tests, a set of three test specimens is to be prepared and the average energy value is to comply with the requirements of subsequent Sections in this Chapter. One individual value may be less than the required average value provided that it is not less than 70 per cent of this value.

1.4.4 Where chemical analysis is required for approval, the results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

Table 11.1.1 Welding consumable grades appropriate to structural and low temperature service steel grades

Consumable grade	Suitable for steel grades (*see* Notes)			
1. Ship Grade Steels (Ch 3,2 and Ch 3,3)				
1N	A	***AH27S***	–	–
2N	B, D	***DH27S***	–	–
3N	E	***EH27S***	–	–
1Y	A	***AH27S***	***AH32***	***AH36***
2Y	B, D	***DH27S***	***DH32***	***DH36***
3Y	E	***EH27S***	***EH32***	***EH36***
4Y	–	***FH27S***	***FH32***	***FH36***
2Y40	***AH32***	***AH36***	***AH40***	–
2Y40	***DH32***	***DH36***	***DH40***	–
3Y40	***EH32***	***EH36***	***EH40***	–
4Y40	***FH32***	***FH36***	***FH40***	–
5Y40	***FH32***	***FH36***	***FH40***	–
2Y47	–	–	***AH40***	***AH47***
2Y47	–	–	***DH40***	***DH47***
3Y47	–	–	***EH40***	***EH47***
4Y47	–	–	***FH40***	***FH47***
2. High Strength Steels (Ch 3,10) *see* Note 3				
3Y42	***AH36***	***AH40***	AH42	–
3Y42	***DH36***	***DH40***	DH42	–
4Y42	***EH36***	***EH40***	EH42	–
5Y42	***FH36***	***FH40***	FH42	–
3Y46	***AH40***	AH42	AH46	–
3Y46	***DH40***	DH42	DH46	–
4Y46	***EH40***	EH42	EH46	–
5Y46	***FH40***	FH42	FH46	–
3Y50	AH42	AH46	AH50	–
3Y50	DH42	DH46	DH50	–
4Y50	EH42	EH46	EH50	–
5Y50	FH42	FH46	FH50	–
3Y55	AH50	AH55	–	–
3Y55	DH50	DH55	–	–
4Y55	EH50	EH55	–	–
5Y55	FH50	FH55	–	–
3Y62	AH55	AH62	–	–
3Y62	DH55	DH62	–	–
4Y62	EH55	EH62	–	–
5Y62	FH55	FH62	–	–
3Y69	AH62	AH69	–	–
3Y69	DH62	DH69	–	–
4Y69	EH62	EH69	–	–
5Y69	FH62	FH69	–	–
3. Ferritic Low Temperature Service Steels (Ch 3,6)				
$1\frac{1}{2}$ Ni	$1\frac{1}{2}$ Ni	–	–	–
$3\frac{1}{2}$ Ni	$3\frac{1}{2}$ Ni	–	–	–
5 Ni	5 Ni	–	–	–
9 Ni	9 Ni	–	–	–

NOTES
1. Steel grades shown in bold italic type include the equivalent (LT-xxxx) low temperature service grades referenced in Ch 3,6.
2. The Table applies to the multi-run welding techniques (i.e. m, S, M).
3. Approval of consumables intended for welding high strength steels in Ch 3,10 also includes the standard ship steel grades as shown in bold italic type and equivalent low temperature service steel grades referenced in Ch 3,6.

1.4.5 LR may require, in any particular case, such additional tests or requirements as may be necessary.

1.4.6 A *List of Approved Welding Consumables* is published by LR.

1.4.7 LR is to be notified of any alteration proposed to be made in the process of manufacture subsequent to approval. Sufficient detail is to be provided to determine the need for further testing to maintain the approval.

1.4.8 Consideration will be given to alternative procedures for approval in the case of manufacturers producing consumables under the control of another manufacturer or plant already having approval of one or more products.

1.5 Annual inspection and tests

1.5.1 All establishments where approved welding consumables are manufactured, and the associated quality control procedures, are to be subjected to annual inspection. On these occasions, samples of the approved consumables are to be selected by the Surveyor and subjected to the tests detailed in subsequent Sections in this Chapter. These are to be completed and reported before the end of the one year period beginning at the initial approval date, and repeated annually so as to provide at least an average of one annual test per year.

1.6 Changes in grading

1.6.1 Changes in grading of welding consumables will be considered only at the manufacturer's request, preferably at the time of annual testing. For upgrading in connection with impact properties, and uprating in connection with tensile properties, tests from butt weld assemblies will be required in addition to the normal annual approval tests. For upgrading in connection with hydrogen testing, specific tests will be required in accordance with ISO 3690. Downgrading and downrating may be imposed by LR where tests and re-tests fail to meet the requirements of this Chapter.

1.7 Manufacturers' Quality Assurance Systems

1.7.1 As an alternative to 1.5, manufacturers may seek maintenance of approval based on acceptance by LR of their 'in house' quality assurance system, and by regular audit of that system carried out in accordance with procedures approved by LR.

1.8 Certification

1.8.1 Each carton or package of approved consumables is to contain a certificate from the manufacturer, generally in accordance with the following: 'The <*insert name of manufacturer*> company certifies that the composition and quality of these consumables conform with those of the consumables used in making the test pieces submitted to and approved by the approval bodies nominated on the label of this package.'

Section 2
Mechanical testing procedures

2.1 Dimensions of test specimens

2.1.1 Dimensions of test pieces for deposited metal tensile tests, butt weld tensile tests, bend tests and Charpy V-notch impact test are to machined to the dimensions and tolerances detailed in Chapter 2.

2.2 Testing procedures

2.2.1 The procedures used for all tensile and impact tests are to comply with the requirements of Chapter 2.

2.2.2 Butt weld bend test specimens are to be tested at ambient temperature and are to be bent through an angle of 120° over a former having a diameter which relates to the thickness of the test specimen as detailed in subsequent Sections. For each pair of bend test specimens, one specimen is to be tested with the face of the weld in tension and the other with the root of the weld in tension.

2.2.3 Macro examinations are to be carried out on polished and etched specimens at a maximum magnification not exceeding x10. The examination is to ensure complete fusion, inter-run penetration and freedom of defects.

2.3 Re-testing procedures

2.3.1 Re-testing procedures are to comply with Ch 2,1.4.

Section 3
Electrodes for manual and gravity welding

3.1 General

3.1.1 Dependent on the results of the mechanical and other tests, approval will be allocated as one of the grades from Table 11.1.1.

3.1.2 Approval of an electrode will be given in conjunction with a welding technique indicated by a suffix ‘m’ for manual welding, ‘G’ for gravity or contact electrode and ‘p’ for deep penetration electrode.

3.1.3 If the electrodes are in compliance with the requirements of the hydrogen test given in 3.4, a suffix ‘H15’ or ‘H10’ or ‘H5’ will be added to the grade mark. Table 11.3.1 shows the mandatory levels of low hydrogen approval for the various approval grades.

3.1.4 For each strength level, electrodes which have satisfied the requirements for a higher toughness grade are considered as complying with the requirements for a lower grade.

Table 11.3.1 Minimum low hydrogen approval requirements for manual and gravity electrodes

Approval grades	Low hydrogen grade required
1 (1N), 2 (2N), 3 (3N)	NR
2Y, 3Y, 4Y	H15 (*see* Note 2)
2Y40 to 5Y40	H15
2Y47 to 4Y47	H10
3Y42 to 5Y42	H10
3Y46 to 5Y46	H10
3Y50 to 5Y50	H10
3Y55 to 5Y55	H5
3Y62 to 5Y62	H5
3Y69 to 5Y69	H5
1½ Ni	H15
3½ Ni	H15
5 Ni	NR (*see* Note 3)
9 Ni	NR (*see* Note 3)

NOTES
1. NR – Not required. Approval may be obtained when requested.
2. Optional in this case. If low hydrogen approval is not obtained, there is a limitation on the carbon equivalent of the steel which is permitted to be welded.
3. Assumes use of an austenitic, non-transformable, filler material.

3.1.5 Electrodes approved for normal and higher strength levels up to and including ‘Y’ are also considered suitable for welding steels in the three strength levels below that for which they have been approved.

3.1.6 Electrodes approved for strength levels Y40 to Y50, but excluding Y47 are also considered suitable for welding steels in two strength levels below that for which they have been approved.

3.1.7 Electrodes approved for strength levels Y47, Y55 and above are also considered suitable for welding steels in only one strength level below that for which they have been approved.

3.1.8 The welding current used is to be within the range recommended by the manufacturer and, where an electrode is stated to be suitable for both a.c. and d.c., a.c. is to be used for the preparation of the test assemblies.

3.1.9 Where an electrode is submitted only for approval for fillet welding and to which the butt weld test provided in 3.3 is not considered applicable, approval tests are to consist of the fillet weld tests as given in 3.5 and deposited metal tests with chemical analyses as given in 3.2.

3.2 Deposited metal test assemblies

3.2.1 The deposited metal test assemblies are to be prepared in the downhand position as shown in Fig. 11.3.1, one with 4 mm diameter electrodes and the other with 8 mm diameter electrodes, or the largest size manufactured if this is less than 8 mm diameter. If an electrode is available in one diameter only, one test assembly is sufficient. Any of the grades of steel in Table 11.1.1 may be used for the preparation of these assemblies, up to a strength level which is not more than two levels above that for which approval is sought.

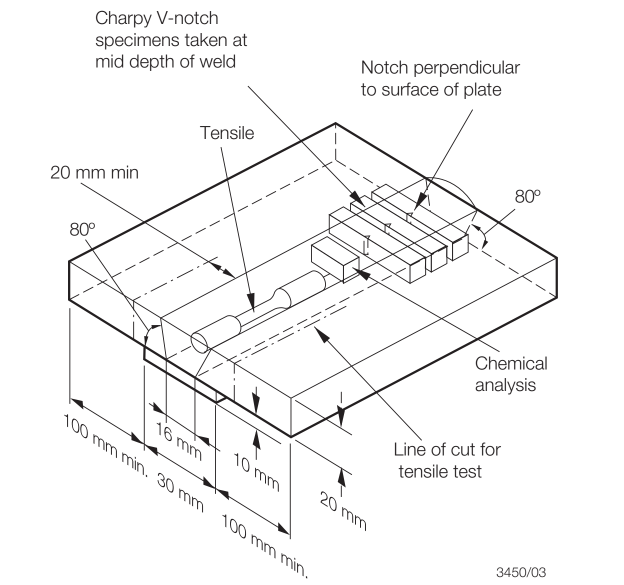


Fig. 11.3.1 Deposited metal test assembly

3.2.2 For Y47 grades, as an alternative to Fig. 11.3.1, the thickness of the plate used for the test assembly may be taken as 50 mm.

3.2.3 The weld metal is to be deposited in single- or multi-run layers according to normal practice, and the direction of deposition of each layer is to alternate from each end of the plate, each run of weld metal being not less than 2 mm and not more than 4 mm thick. Between each run, the assembly is to be left in still air until it has cooled to less than 250°C, the temperature being taken in the centre of the weld, on the surface of the seam. After being welded, the test assemblies are not to be subjected to any heat treatment, except in those higher strength grades where it is considered necessary to use the welded joint in the stress-relieved (tempered) condition. In those cases, the code 'sr' will be added to the approval grading.

3.2.4 The chemical analysis of the deposited weld metal in each deposited metal test assembly is to be supplied by the manufacturer and is to include the content of all significant alloying elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

3.2.5 One tensile and three impact test specimens are to be taken from each test assembly as shown in Fig. 11.3.1. Care is to be taken that the axis of the tensile test specimen coincides with the centre of the weld and the mid-thickness of the plates. The impact test specimens are to be cut perpendicular to the weld, with their axes 10 mm from the upper surface. The notch is to be positioned in the centre of the weld and cut in the face of the test specimen perpendicular to the surface of the plate.

3.2.6 The results of all tests are to comply with the requirements of Table 11.3.2 as appropriate.

3.3 Butt weld test assemblies

3.3.1 Butt weld assemblies, as shown in Fig. 11.3.2, are to be prepared for each welding position (downhand, horizontal-vertical, vertical-upward, vertical-downward, and overhead) for which the electrode is recommended by the manufacturer. In the case of electrodes for normal strength and higher strength steels (up to 355 N/mm^2 minimum specified yield strength), electrodes satisfying the requirements for downhand and vertical-upward positions will be considered as also complying with the requirements for the horizontal-vertical position. In all other cases, approval for the horizontal-vertical position will require a butt weld to be made in that position and fully tested.

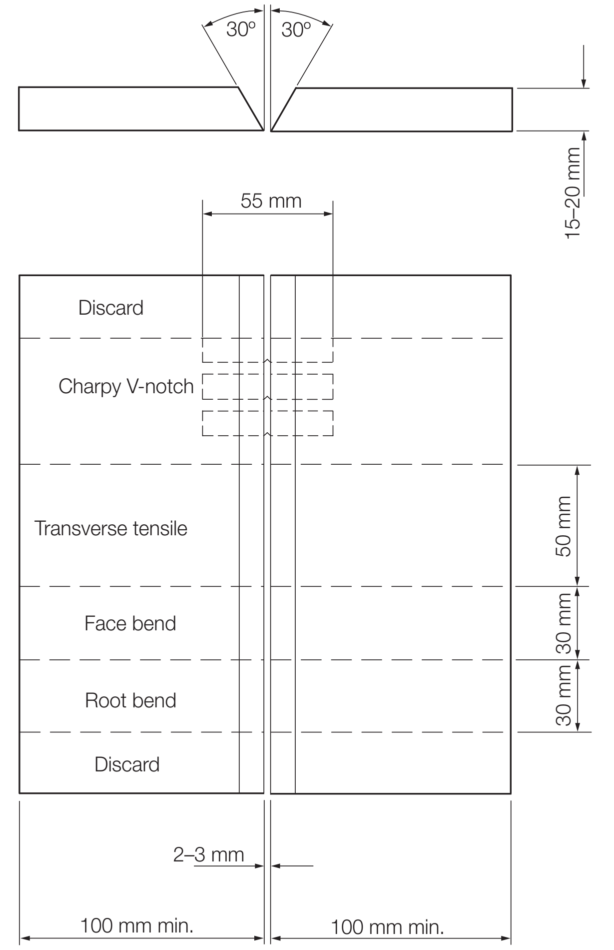


Fig. 11.3.2 Butt weld test assembly

3.3.2 For Y47 grades, as an alternative to Fig. 11.3.2 the thickness of the plate used for the test assembly may be taken as 50 mm.

3.3.3 Where the electrode is to be approved only in the downhand position, an additional test assembly is to be prepared in that position.

Table 11.3.2 Requirements for deposited metal tests (covered electrodes)

Grade (*see* Note 3)	Yield stress N/mm² minimum	Tensile strength N/mm² (*see* Note 1)	Elongation on 50 mm % minimum	Charpy V-notch impact tests	
				Test temperature °C	Average energy (*see* Note 2) J minimum
1N, 2N, 3N	305	400 – 560	22	+20, 0, –20	47
1Y, 2Y, 3Y, 4Y	375	490 – 660	22	+20, 0, –20, –40	47
2Y40, 3Y40, 4Y40, 5Y40	400	510 – 690	22	0, –20, –40, –60	47
2Y47, 3Y47, 4Y47	460	570 – 720	19	0, –20, –40	53
3Y40	400	510 – 690	22	–20	47
3Y42	420	530 – 680	20	–20	47
3Y46	460	570 – 720	20	–20	47
3Y50	500	610 – 770	18	–20	50
3Y55	550	670 – 830	18	–20	55
3Y62	620	720 – 890	18	–20	62
3Y69	690	770 – 940	17	–20	69
4Y40	400	510 – 690	22	–40	47
4Y42	420	530 – 680	20	–40	47
4Y46	460	570 – 720	20	–40	47
4Y50	500	610 – 770	18	–40	50
4Y55	550	670 – 830	18	–40	55
4Y62	620	720 – 890	18	–40	62
4Y69	690	770 – 940	17	–40	69
5Y40	400	510 – 690	22	–60	47
5Y42	420	530 – 680	20	–60	47
5Y46	460	570 – 720	20	–60	47
5Y50	500	610 – 770	18	–60	50
5Y55	550	670 – 830	18	–60	55
5Y62	620	720 – 890	18	–60	62
5Y69	690	770 – 940	17	–60	69
$1^1/_2$ Ni	375	460	22	–80	34
$3^1/_2$ Ni	375	420	25	–100	34
5 Ni	375	500	25	–120	34
9 Ni	375	600	25	–196	34

NOTES
1. Single values are the minimum requirements.
2. Energy values from individual impact test specimens are to comply with 1.4.3.
3. Grade 1Y is not applicable to SMAW consumables referenced in Section 3.

3.3.4 The grades of steel used for the preparation of the test assemblies are to be as follows:

Grade 1 (1N) electrodes	A
Grade 2 (2N) electrodes	A, B or D
Grade 3 (3N) electrodes	A, B, D or E
Grade 2Y electrodes	AH32, AH36, DH32 or DH36
Grade 3Y electrodes	AH32, AH36, DH32, DH36, EH32 or EH36
Grade 4Y electrodes	AH32 AH36, DH32, DH36, EH32, EH36, FH32 or FH36
Grade 2Y40 electrodes	AH40 or DH40
Grade 3Y40 electrodes	AH40, DH40 or EH40
Grade 4Y40 electrodes	AH40, DH40, EH40 or FH40
Grade 5Y40 electrodes	AH40, DH40, EH40 or FH40
Grade 2Y47 electrodes	AH47, DH47
Grade 3Y47 electrodes	AH47, DH47, EH47
Grade 4Y47 electrodes	AH47, DH47, EH47 or FH47

Where Grade 32 higher tensile steel is used, the tensile strength is to be not less than 490 N/mm². The chemical composition, including the content of grain refining elements, is to be reported in all cases where higher tensile steel is used.

3.3.5 For all other grades, the steel plates used are to be selected by reference to Table 11.1.1, and are to have at least their chemical composition and tensile properties within the limits specified for that grade in Chapter 3. The strength grade used is to be the same as that for which approval is sought, and the toughness grade is to be no higher than that for which approval is also sought.

3.3.6 The test assemblies are to be made by welding together two plates of equal thickness (15 to 20 mm), not less than 100 mm in width and of sufficient length to allow the cutting out of test specimens of the prescribed number and size. The plate edges are to be prepared to form a single V-joint, the included angle between the fusion faces being 60° and the root gap 2 to 3 mm. The root face is to be 0 to 2 mm.

3.3.7 The following welding procedure is to be adopted in making the test assemblies:

Downhand (a). The first run with 4 mm diameter electrode. Remaining runs (except the last two layers) with 5 mm diameter electrodes or above according to the normal welding practice with the electrodes. The runs of the last two layers with the largest diameter of electrode manufactured or 8 mm whichever is the lesser.

Downhand (b) (where a second downhand test is required). First run with 4 mm diameter electrode. Next run with an electrode of intermediate diameter of 5 mm or 6 mm, and the remaining runs with the largest diameter of electrode manufactured or 8 mm whichever is the lesser.

Horizontal-vertical. First run with 4 mm or 5 mm diameter electrode. Subsequent runs with 5 mm diameter electrodes.

Vertical-upward and overhead. First run with 3,25 mm diameter electrode. Remaining runs with 4 mm diameter electrodes or possibly with 5 mm if this is recommended by the manufacturer for the positions concerned.

Vertical-downward. If the electrode being tested is intended for vertical welding in the downward direction, this technique is to be adopted for the preparation of the test assembly using electrode diameters as recommended by the manufacturer.

3.3.8 For all assemblies, the back sealing runs are to be made with 4 mm diameter electrodes in the welding position appropriate to each test sample, after cutting out the root run to clean metal. For electrodes suitable for downhand welding only, the test assemblies may be turned over to carry out the back sealing run.

3.3.9 Normal welding practice is to be used and, between each run, the assembly is to be left in still air until it has cooled to less than 250°C, the temperature being taken in the centre of the weld, on the surface of the seam. After being welded, the test assemblies are not to be subjected to any heat treatment, except in those higher strength grades where it is considered necessary to use the welded joint in the stress-relieved (tempered) condition. In those cases, the code ‘sr’ will be added to the approval grading.

3.3.10 It is recommended that the welded assemblies be subjected to a radiographic examination to ascertain if there are any defects in the weld prior to the preparation of test specimens.

3.3.11 The test specimens as shown in Figs. 11.3.2 and 11.3.3 are to be prepared from each test assembly.

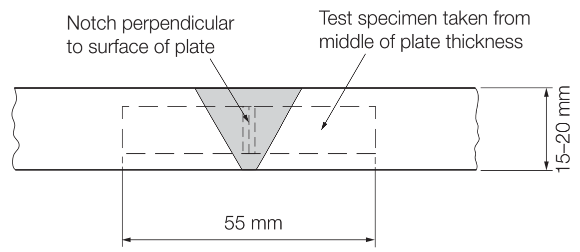


Fig. 11.3.3
Butt weld test assembly position of impact test specimens

3.3.12 The results of all tensile and impact tests are to comply with the requirements of Table 11.3.3 as appropriate. The position of fracture in the transverse tensile test is to be reported.

3.3.13 The bend test specimens can be considered as complying with the requirements if, after bending, no crack or other open defect exceeding 3 mm in dimensions can be seen on the outer surface.

3.4 Hydrogen test

3.4.1 The hydrogen gradings are specified in 3.1.3. The hydrogen grading required determines the method of testing permitted as shown in Table 11.3.4. Where ISO 3690 is used as the testing method, three test specimens are to be prepared and tested, and all three hydrogen test results must be below the maximum value for the hydrogen mark required.

3.5 Fillet weld test assemblies

3.5.1 Fillet weld assemblies as shown in Fig. 11.3.4 are to be prepared for each welding position (horizontal-vertical, vertical-upward, vertical-downward or overhead) for which the electrode is recommended by the manufacturer. The grade of steel used for the test assemblies is to be as detailed in 3.3.4. The length of the test assembly, *L*, is to be sufficient to allow at least the deposition of the entire length of the largest diameter electrode being tested. Where an electrode is submitted for approval of both butt and fillet welding, approval tests are to include the deposited metal tests as given in 3.2, the butt weld tests as given in 3.3, and only one fillet weld test as given in subsequent paragraphs of this sub-Section welded in the horizontal-vertical position.

3.5.2 For Y47 grades, as an alternative to Fig. 11.3.4, the thickness of the plate used for the test assembly may be taken as 50 mm.

Table 11.3.3 Requirements for butt weld tests (covered electrodes)

Grade (*see* Note 3)	Tensile strength N/mm^2	Bend test ratio: $\frac{D}{t}$	Charpy V-notch impact tests: Test temperature °C	Charpy V-notch impact tests: Average energy (*see* Note 1) J minimum, All positions (*see* Note 2)
1N, 2N, 3N	400	3	+20, 0, –20	47 (34)
1Y, 2Y, 3Y, 4Y	490	3	+20, 0, –20, –40	47 (34)
2Y40, 3Y40, 4Y40, 5Y40	510	3	0, –20, –40, –60	47 (39)
2Y47, 3Y47, 4Y47	570 – 720	4	0, –20, –40	53
3Y40	510	3	–20	47 (39)
3Y42	530 – 680	4	–20	47
3Y46	570 – 720	4	–20	47
3Y50	610 – 770	4	–20	50
3Y55	670 – 830	5	–20	55
3Y62	720 – 890	5	–20	62
3Y69	770 – 940	5	–20	69
4Y40	510	3	–40	47 (39)
4Y42	530 – 680	4	–40	47
4Y46	570 – 720	4	–40	47
4Y50	610 – 770	4	–40	50
4Y55	670 – 830	5	–40	55
4Y62	720 – 890	5	–40	62
4Y69	770 – 940	5	–40	69
5Y40	510	3	–60	39
5Y42	530 – 680	4	–60	47
5Y46	570 – 720	4	–60	47
5Y50	610 – 770	4	–60	50
5Y55	670 – 830	5	–60	55
5Y62	720 – 890	5	–60	62
5Y69	770 – 940	5	–60	69
1^1/2 Ni	490	3	–80	27
3^1/2 Ni	450	3	–100	27
5 Ni	540	4	–120	27
9 Ni	640	4	–196	27

NOTES
1. Energy values from individual impact test specimens are to comply with 1.4.3.
2. Values in ( ) apply only to welds made in the vertical position with upward progression.
3. Grade 1Y is not applicable to SMAW consumables referenced in Section 3.

Table 11.3.4 Permitted methods for obtaining low hydrogen grading

Hydrogen Grade	Permitted Method
H15	ISO 3690 (or Glycerine) (*See* Note)
H10	ISO 3690
H5	ISO 3690

NOTE
ISO method preferred.

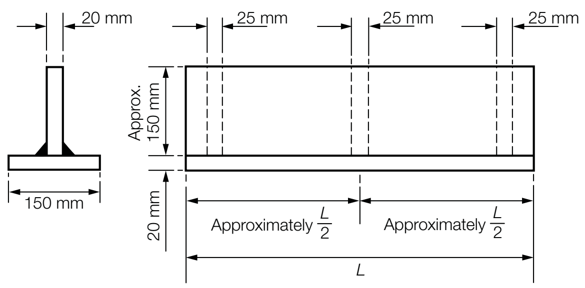


Fig. 11.3.4 Fillet weld test assembly

3.5.3 The electrode sizes to be used are the maximum and minimum diameters recommended by the manufacturer for fillet welding. The first side is to be welded using the maximum diameter. The second side is to be welded only after the assembly has been allowed to cool below 50°C using the minimum diameter. The size of these single run fillet welds will, in general, be determined by the electrode size and the welding current employed during testing and should represent the range of fillet weld bead sizes recommended by the manufacturer.

3.5.4 Each test assembly is to be sectioned to form three macro-sections, each about 25 mm thick. These are to be examined for root penetration, satisfactory profile, freedom from cracking and reasonable freedom from porosity and slag inclusions. Any undercut is not to exceed 0,5 mm in depth. Convexity or concavity of the profile is not to exceed one-tenth of the fillet bead throat dimension. All such observations are to be reported.

3.5.5 Hardness measurements are to be made on the central macro-section only, as shown in Fig. 11.3.5. The results are to be reported.

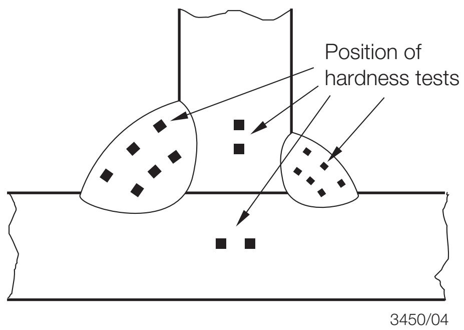


Fig. 11.3.5
Hardness tests for fillet weld test assembly

3.5.6 One of the remaining sections of the assembly is to have the weld on the first side gouged or machined to facilitate breaking the fillet weld on the second side by closing the two plates together, subjecting the root of the weld to tension. On the other remaining section, the weld on the second side is to be gouged or machined and the section fractured using the same procedure. The fractured surfaces are to be examined. They are to show satisfactory penetration, freedom from cracks and reasonable freedom from porosity and this should be reported.

3.6 Electrodes designed for deep penetration welding

3.6.1 Where an electrode is designed solely for the deep penetration welding of downhand butt joints and horizontal-vertical fillets in normal tensile strength steel, only the tests detailed in 3.7 and 3.8 are required for approval purposes.

3.6.2 Electrodes designed solely for the deep penetration welding technique will be approved as complying with Grade 1 requirements only and will be given the suffix ‘p’.

3.6.3 Where a manufacturer recommends that an electrode having deep penetrating properties can also be used for downhand butt welding of thicker plates with prepared edges, the electrode will be treated as a normal penetration electrode, and the full series of tests in the downhand position is to be carried out, together with the deep penetration tests given in 3.7 and 3.8.

3.6.4 Where a manufacturer desires to demonstrate that an electrode, in addition to its use as a normal penetration electrode, also has deep penetrating properties when used for downhand butt welding and horizontal fillet welding, the additional tests given in 3.7 and 3.8 are to be carried out.

3.6.5 Electrodes approved for both normal and deep penetration welding will have the suffix ‘p’ added after the appropriate grade mark for normal penetration welding.

3.6.6 Where the manufacturer prescribes a different welding current and procedure for the electrode when used as a deep penetration electrode and a normal penetration electrode, the recommended current and procedure are to be used when making the test assemblies in each case.

3.7 Deep penetration butt weld test assemblies

3.7.1 Two plates of thickness equal to twice the diameter of the core of the electrode plus 2 mm are to be butt welded together with one downhand run of welding from each side. The plates are to be not less than 100 mm wide and of sufficient length to allow the cutting out of the test specimens of the correct number and size as shown in Fig. 11.3.6. Grade A steel is to be used for these test assemblies. The joint edges are to be prepared square and smooth and, after tacking, the gap is not to exceed 0,25 mm. The test assembly is to be welded using an 8 mm diameter electrode, or the largest diameter manufactured if this is less than 8 mm and the assembly is to be allowed to cool below 50°C between runs.

3.7.2 The test specimens as shown in Figs. 11.3.3 and 11.3.6 are to be prepared from each test assembly.

3.7.3 The results of tensile and impact tests are to comply with the requirements of Table 11.3.3 for Grade 1 electrodes. The position of fracture in the tensile test is to be reported. The bend test specimens are to be in accordance with 3.3.13.

3.7.4 The discards at the end of the welded assemblies are to be not more than 35 mm wide. The joints of these discards are to be polished and etched and must show complete fusion and inter-penetration of the weld beads. At each cut in the test assembly, the joints are also to be examined to ensure that complete fusion has taken place.

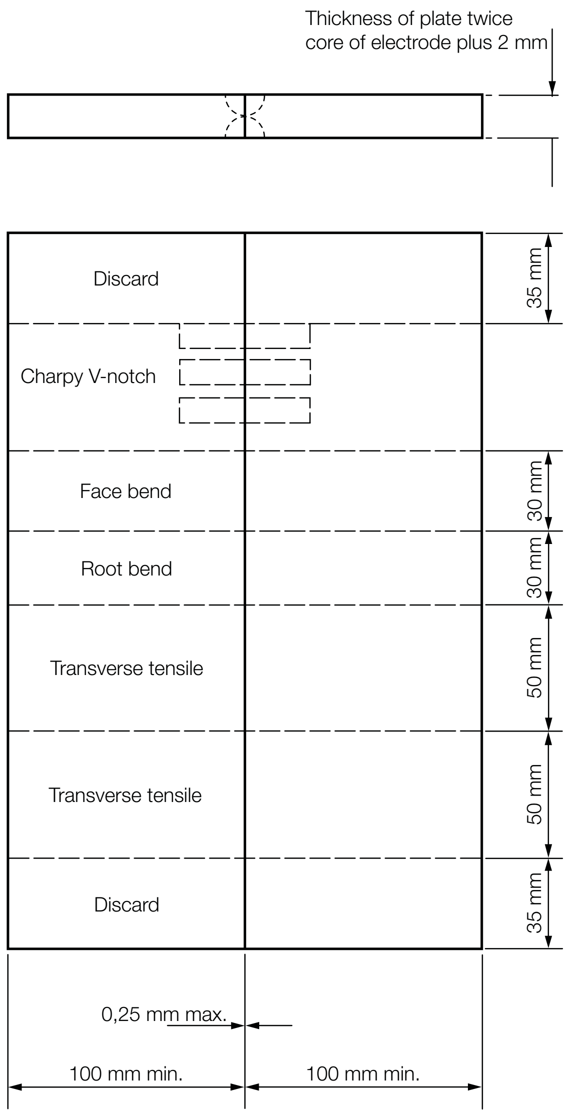


Fig. 11.3.6
Deep penetration butt weld test assembly

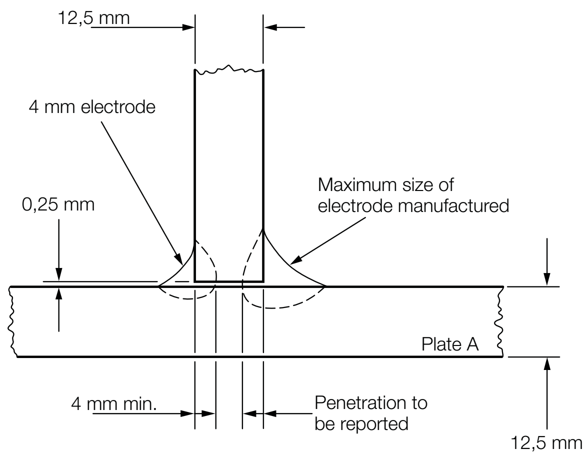


Fig. 11.3.7
Deep penetration fillet weld test assembly

3.8 Deep penetration fillet weld test assemblies

3.8.1 A fillet weld assembly is to be prepared as shown in Fig. 11.3.7 with plates about 12,5 mm in thickness. The welding is to be carried out with one run for each fillet with plate A in the horizontal plane during the welding operations. The length of the fillet is to be 160 mm and the gap between the plates is to be not more than 0,25 mm. Grade A steel is to be used for these test assemblies.

3.8.2 The fillet weld on one side of the assembly is to be carried out with a 4 mm diameter electrode, and that on the other side with the maximum diameter of electrode manufactured. The welding current used is to be within the range recommended by the manufacturer, and the welding is to be carried out using normal welding practice except that the assembly is to be allowed to cool below 50°C between runs.

3.8.3 The welded assembly is to be cut by sawing or machining within 35 mm of the ends of the fillet welds, and the joints are to be polished and etched. The welding of the fillet made with a 4 mm diameter electrode is to show a penetration of 4 mm (*see* Fig. 11.3.7) and the corresponding penetration of the fillet made with the maximum diameter of electrode manufactured is to be reported.

3.9 Electrodes designed for gravity or contact welding

3.9.1 Approval for welding using the gravity, 'G', technique is available for welding only normal strength and higher tensile steels up to and including Grade 36.

3.9.2 Where an electrode is submitted solely for approval for use in contact welding using automatic gravity or similar welding devices, deposited metal tests, butt weld tests and, where appropriate, fillet weld tests similar to those for normal manual electrodes are to be carried out using the process for which the electrode is recommended by the manufacturer.

3.9.3 Where an electrode is submitted for approval for use in contact welding using automatic gravity or similar welding devices in addition to normal manual welding, butt weld and, where appropriate, fillet weld tests, using the gravity or other contact device as recommended by the manufacturer, are to be carried out in addition to the normal approval tests.

3.10 Annual tests

3.10.1 For normal penetration electrodes, the annual tests are to consist of two deposited metal test assemblies. These are to be prepared and tested in accordance with 3.2. If an electrode is available in one diameter only, one test assembly is sufficient.

3.10.2 Where an electrode is approved solely for deep penetration welding, the annual test is to consist of one butt welded test assembly. This is to be prepared and tested in accordance with 3.7.

3.10.3 Where an electrode is approved for both normal and deep penetration welding, annual tests as detailed in 3.10.1 and 3.10.2 are to be carried out.

3.10.4 Where an electrode is approved solely for gravity or contact welding, the annual test is to consist of one deposited metal test assembly using the gravity or other contact device as recommended by the manufacturer.

3.10.5 Where an electrode is approved for both manual and gravity welding, annual tests as detailed in 3.10.1 and 3.10.4 are to be carried out.

■ *Section 4* **Wire-flux combinations for submerged-arc automatic welding**

4.1 General

4.1.1 Wire-flux combinations for single and multiple electrode submerged-arc automatic welding, without the use of temporary backing, are divided into the following two categories:
- For use with the multi-run technique.
- For use with the two-run technique.

Where particular wire-flux combinations are intended for welding with both techniques, tests are to be carried out for each technique.

4.1.2 Dependent on the results of mechanical and other tests, approval will be allocated as one of the grades from Table 11.1.1.

4.1.3 The suffixes T or M will be added after the grade mark to indicate approval for the two-run technique or, multi-run technique respectively.

4.1.4 Wire-flux combinations satisfying the requirements for multi-run or two-run techniques will also be approved for fillet welding in the downhand and horizontal-vertical position, subject to agreement by the manufacturer.

4.1.5 If the consumable combination is in compliance with the requirements of the hydrogen test given in 3.4, a suffix H15, H10 or H5 will be added to the grade. Table 11.4.1 shows the mandatory levels of low hydrogen approval for the various approval grades.

4.1.6 For each strength level, wire-flux combinations which have satisfied the requirements for a higher toughness grade are considered as complying with the requirements for a lower grade.

Table 11.4.1 Minimum low hydrogen approval requirements for wire-flux combinations

Approval grade	'H' grade for Multi-run	'H' grade for Two-run
1 (1N), 2 (2N), 3 (3N)	NR	NR
1Y, 2Y, 3Y, 4Y	NR	NR
2Y40 to 5Y40	H15	NR
2Y47 to 4Y47	H10	H15
3Y42 to 5Y42	H10	H15
3Y46 to 5Y46	H10	H15
3Y50 to 5Y50	H10	H10
3Y55 to 5Y55	H5	H10
3Y62 to 5Y62	H5	H5
3Y69 to 5Y69	H5	H5
$1^1/_2$ Ni	H15	NR
$3^1/_2$ Ni	H15	NR
5 Ni (*see* Note 2)	NR	NR
9 Ni (*see* Note 2)	NR	NR

NOTES
1. NR – Not required. Approval can be obtained when requested.
2. Assumes use of an austenitic, non-transformable, filler material.

4.1.7 Wire-flux combinations approved with multi-run technique for normal and higher strength levels up to and including 'Y' are also considered suitable for welding steels in the three strength levels below that for which they have been approved.

4.1.8 Wire-flux combinations approved with multi-run technique for strength levels Y40 to Y50, but excluding Y47 are also considered suitable for welding steels in two strength levels below that for which they have been approved.

4.1.9 Wire-flux combinations approved with multi-run technique for strength levels Y47, Y55 and above are also considered suitable for welding steels in only one strength level below that for which they have been approved.

4.1.10 Wire-flux combinations with two-run technique approval are not considered suitable for welding steels of any other strength level with that technique, *see* 4.5.1.

4.1.11 The welding current may be either a.c. or d.c. (electrode positive or negative) according to the recommendation of the manufacturer. If both a.c. and d.c. are recommended, a.c. is to be used for the tests.

4.1.12 Wire-flux combinations for multiple electrode submerged-arc welding will be subject to separate approval tests. These are to be carried out generally in accordance with the requirements of this Section.

4.1.13 Wire-flux combinations are not naturally low hydrogen in character, but for the lower strength grades of steel low hydrogen testing is not normally a requirement for approval. With higher strength steels it is more important and Table 11.4.1 shows the mandatory minimum low hydrogen status required for approval of wire-flux combinations.

4.2 Approval tests for multi-run technique

4.2.1 Where approval for use with the multi-run technique is requested, deposited metal and butt weld tests are to be carried out.

4.3 Deposited metal test assemblies (multi-run technique)

4.3.1 One deposited metal test assembly is to be prepared as shown in Fig. 11.4.1, using any of the grades of steel in Table 11.1.1 up to a strength level which is not more than two levels above that for which approval is sought.

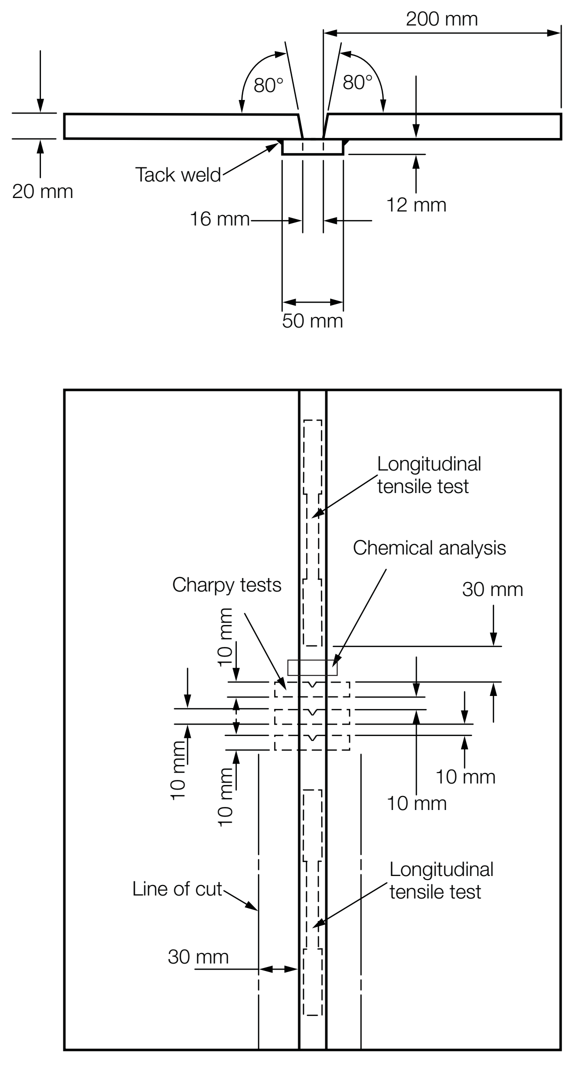


Fig. 11.4.1 Deposited metal test assembly

4.3.2 For Y47 grades, as an alternative to Fig. 11.4.1, the thickness of the plate used for the test assembly may be taken as 50 mm.

4.3.3 The bevelling of the plate edges is to be carried out by machining or mechanised gas cutting. In the latter case any remaining scale is to be removed from the bevelled edges.

4.3.4 Welding is to be in the downhand position, and the direction of deposition of each run is to alternate from each end of the plate. After completion of each run, the flux and welding slag are to be removed. Between each run, the assembly is to be left in still air until it has cooled to less than 250°C, the temperature being taken in the centre of the weld, on the surface of the seam. The thickness of the layer is to be not less than the diameter of the wire nor less than 4 mm, unless it is clearly stated as part of the consumable manufacturer's published recommendations.

4.3.5 The welding conditions (amperage, voltage and rate of travel) are to be in accordance with the recommendations of the manufacturer and are to conform with normal good welding practice for multi-run welding.

4.3.6 The chemical analysis of the deposited weld metal in each test assembly is to be supplied by the manufacturer and is to include the content of all significant alloying elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

4.3.7 Two longitudinal tensile and three impact test specimens are to be taken from each test assembly as shown in Fig. 11.4.1. Care is to be taken that the axes of the tensile test specimens coincide with the centre of the weld and the mid-thickness of the plates. The impact test specimens are to be cut perpendicular to the weld with their axes 10 mm from the upper surface. The notch is to be positioned in the centre of the weld and cut in the face of the test specimen perpendicular to the surface of the plate.

4.3.8 In those cases where two-run technique approval is also sought, only one longitudinal tensile specimen need be prepared and tested from this assembly.

4.3.9 The results of all tests are to comply with the requirements of Table 11.4.2, as appropriate.

4.4 Butt weld test assemblies (multi-run technique)

4.4.1 One butt weld test assembly is to be prepared as shown in Fig. 11.4.2.

Table 11.4.2 Requirements for deposited metal tests (wire-flux combinations)

Grade	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on 50 mm % minimum	Charpy V-notch impact tests	
				Test temperature °C	Average energy (*see* Note) J minimum
1N, 2N, 3N	305	400 – 560	22	+20, 0, –20	34
1Y, 2Y, 3Y, 4Y	375	490 – 660	22	+20, 0, –20, –40	34
2Y40, 3Y40, 4Y40, 5Y40	400	510 – 690	22	0, –20, –40, –60	39
2Y47, 3Y47, 4Y47	460	570 – 720	19	0, –20, –40	53
3Y40	400	510 – 690	22	–20	39
3Y42	420	530 – 680	20	–20	47
3Y46	460	570 – 720	20	–20	47
3Y50	500	610 – 770	18	–20	50
3Y55	550	670 – 830	18	–20	55
3Y62	620	720 – 890	18	–20	62
3Y69	690	770 – 940	17	–20	69
4Y40	400	510 – 690	22	–40	39
4Y42	420	530 – 680	20	–40	47
4Y46	460	570 – 720	20	–40	47
4Y50	500	610 – 770	18	–40	50
4Y55	550	670 – 830	18	–40	55
4Y62	620	720 – 890	18	–40	62
4Y69	690	770 – 940	17	–40	69
5Y40	400	510 –690	22	–60	39
5Y42	420	530 – 680	20	–60	47
5Y46	460	570 – 720	20	–60	47
5Y50	500	610 – 770	18	–60	50
5Y55	550	670 – 830	18	–60	55
5Y62	620	720 – 890	18	–60	62
5Y69	690	770 – 940	17	–60	69
1½ Ni	375	460	22	–80	34
3½ Ni	375	420	25	–100	34
5 Ni	375	500	25	–120	34
9 Ni	375	600	25	–196	34

NOTE
Energy values from individual impact test specimens are to comply with 1.4.3.

4.4.2 The grade of steel used for the preparation of the test assembly are to be as follows:

Grade 1 wire-flux combination	A
Grade 2 wire-flux combinations	A, B or D
Grade 3 wire-flux combinations	A, B, D or E
Grade 1Y wire-flux combination	AH32 or AH36
Grade 2Y wire-flux combinations	AH32, AH36, DH32 or DH36
Grade 3Y wire-flux combinations	AH32, AH36, DH32, DH36, EH32 or EH36
Grade 4Y wire-flux combinations	AH32, AH36, DH32, DH36, EH32, EH36, FH32 or FH36
Grade 2Y40 wire-flux combination	AH40 or DH40
Grade 3Y40 wire-flux combinations	AH40, DH40 or EH40
Grade 4Y40 wire-flux combinations	AH40, DH40, EH40 or FH40
Grade 5Y40 wire-flux combinations	AH40, DH40 EH40, FH40
Grade 2Y47 wire-flux combinations	AH47 or DH47
Grade 3Y47 wire-flux combinations	AH47, DH47 or EH47
Grade 4Y47 wire-flux combinations	AH47, DH47, EH47 or FH47

Where Grade 32 higher tensile steel is used, the tensile strength is to be not less than 490 N/mm^2. The chemical composition, including the content of grain refining elements, is to be reported in all cases where higher tensile steel is used.

4.4.3 For all other grades, the steel plates used are to be selected by reference to Table 11.1.1, and are to have at least their chemical composition and tensile properties within the limits specified for that grade in Chapter 3. The strength grade used is to be the same as that for which approval is sought, and the toughness grade is to be no higher than that for which approval is also sought.

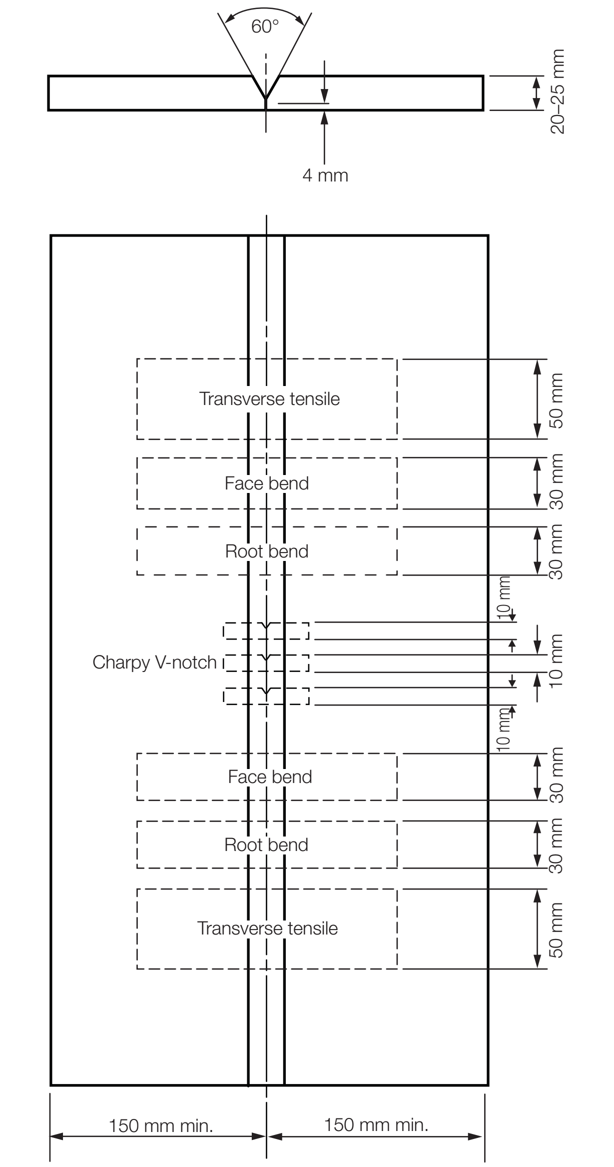


Fig. 11.4.2
Butt weld test assembly (multi-run technique)

4.4.4 The plate edges are to be prepared to form a single V-joint, the included angle between the fusion faces being 60° and the root face being 4 mm. The bevelling of the plate edges is to be carried out by machining or mechanised gas cutting. In the latter case, any remaining scale is to be removed from bevelled edges.

4.4.5 Welding is to be carried out in the downhand position by the multi-run technique, and the welding conditions are to be the same as those adopted for the deposited metal test assembly. The back sealing run is to be applied in the downhand position after cutting out the root run to clean metal.

4.4.6 It is recommended that the welded assembly be subjected to a radiographic examination to ascertain if there are any defects in the weld prior to the preparation of test specimens.

4.4.7 The test specimens as shown in Fig. 11.3.3 and Fig. 11.4.2 are to be prepared from each test assembly.

4.4.8 The results of all tensile and impact tests are to comply with the requirements of Table 11.4.3, as appropriate. The position of fracture of the transverse tensile test is to be reported.

4.4.9 The bend test specimens can be considered as complying with the requirements if, after bending, no cracks or other open defects exceeding 3 mm in dimension can be seen on the outer surface.

4.5 Approval tests for two-run technique

4.5.1 Where approval for use with the two-run technique is requested, two butt weld test assemblies are to be prepared and tested using plates of the strength level for which approval is required. Each strength level requires separate approval.

4.5.2 Two welded assemblies are to be made from a pair of plates of matching thicknesses. The thickness of the thicker pair of plates will be the maximum for which the approval is valid. The second assembly is to be welded from plates having approximately half of the thickness of the first assembly.

4.6 Butt weld test assemblies (two-run technique)

4.6.1 The grade of steel used for the preparation of the test assemblies is not to be of any higher grade (impact toughness) than that for which approval is required. The chemical composition, including the content of grain refining elements, and the strength properties of the plates used, are to be reported.

4.6.2 The maximum diameter of wire and the edge preparation to be used are to be in accordance with Table 11.4.4. Small deviations in the edge preparation may be allowed if requested by the manufacturer. The bevelling of the plate edges is to be performed by machining or mechanised gas cutting. In the latter case, any remaining scale is to be removed from the bevelled edges. The root gap should not exceed 0,7 mm.

4.6.3 Each butt weld is to be welded in two runs, one from each side, using amperages, voltages and travel speeds in accordance with the recommendations of the manufacturer and normal good welding practice. After completion of the first run, the flux and welding slag are to be removed and the assembly is to be left in still air until it has cooled to less than 100°C, the temperature being taken in the centre of the weld, on the surface of the seam.

4.6.4 It is recommended that the butt weld assemblies be subjected to radiographic examination to ascertain if there are any defects in the weld prior to the preparation of test specimens.

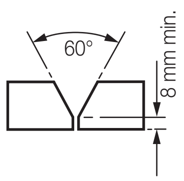
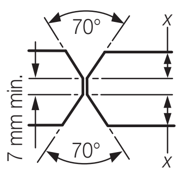
4.6.5 The test specimens, as shown in Fig. 11.4.3 and Fig. 11.4.4, are to be prepared from each test assembly, except as detailed in 4.6.8. The edges of two of the discards are to be polished and etched, and must show complete fusion and inter-run penetration of the welds. At each cut in the test assembly, the edges are also to be examined to ensure that complete fusion has taken place.

Table 11.4.3 Requirements for butt weld tests (wire-flux combinations)

Grade	Tensile strength N/mm^2	Bend test ratio: $\frac{D}{t}$	Charpy V-notch impact tests	
			Test temperature °C	Average energy (*see* Notes 1 and 2) J minimum
1N, 2N, 3N	400	3	+20, 0, –20	34
1Y, 2Y, 3Y, 4Y	490	3	+20, 0, –20, –40	34
2Y40, 3Y40, 4Y40, 5Y40	510	3	0, –20, –40, –60	39
2Y47, 3Y47, 4Y47	570 – 720	4	0, –20, –40	53
3Y40	510	3	–20	39
3Y42	530 – 680	4	–20	47 (41)
3Y46	570 – 720	4	–20	47
3Y50	610 – 770	4	–20	50
3Y55	670 – 830	5	–20	55
3Y62	720 – 890	5	–20	62
3Y69	770 – 940	5	–20	69
4Y40	510	3	–40	39
4Y42	530 – 680	4	–40	47 (41)
4Y46	570 – 720	4	–40	47
4Y50	610 – 770	4	–40	50
4Y55	670 – 830	5	–40	55
4Y62	720 – 890	5	–40	62
4Y69	770 – 940	5	–40	69
5Y40	510	3	–60	39
5Y42	530 – 680	4	–60	47 (41)
5Y46	570 – 720	4	–60	47
5Y50	610 – 770	4	–60	50
5Y55	670 – 830	5	–60	55
5Y62	720 – 890	5	–60	62
5Y69	770 – 940	5	–60	69
1½ Ni	490	3	–80	27
3½ Ni	450	3	–100	27
5 Ni	540	4	–120	27
9 Ni	640	4	–196	27

NOTES
1. Energy values from individual impact test specimens are to comply with 1.4.3.
2. Values in ( ) apply only to two-run technique impact test specimens.

Table 11.4.4 Butt weld assembly preparation

Plate thickness mm	Recommended diameter	Maximum diameter of wire mm
12,5		5
20–25		6
35–40		7

4.6.6 The results of transverse tensile and impact tests are to comply with the requirements of Table 11.4.3 as appropriate. The position of fracture of the transverse tensile tests is to be reported.

4.6.7 The bend test specimens can be considered as complying with the requirements if, after bending, no crack or other open defects exceeding 3 mm in dimensions can be seen on the outer surface. One of the specimens from each assembly is to be tested with the side first welded in tension, and the second specimen with the other side in tension.

4.6.8 The longitudinal tensile specimen shown in Fig. 11.4.3 is to be prepared from the thicker assembly, even in those cases where multi-run technique approval is also sought. This test specimen is to be machined to the dimensions shown in Ch 11,2.1.1, and the longitudinal axis is to coincide with the centre of the weld about 7 mm below the plate surface on the side from which the second run is made. The test specimen may be given a hydrogen release treatment in accordance with 2.1.1. The results of this test are to comply with the requirements of Table 11.4.2.

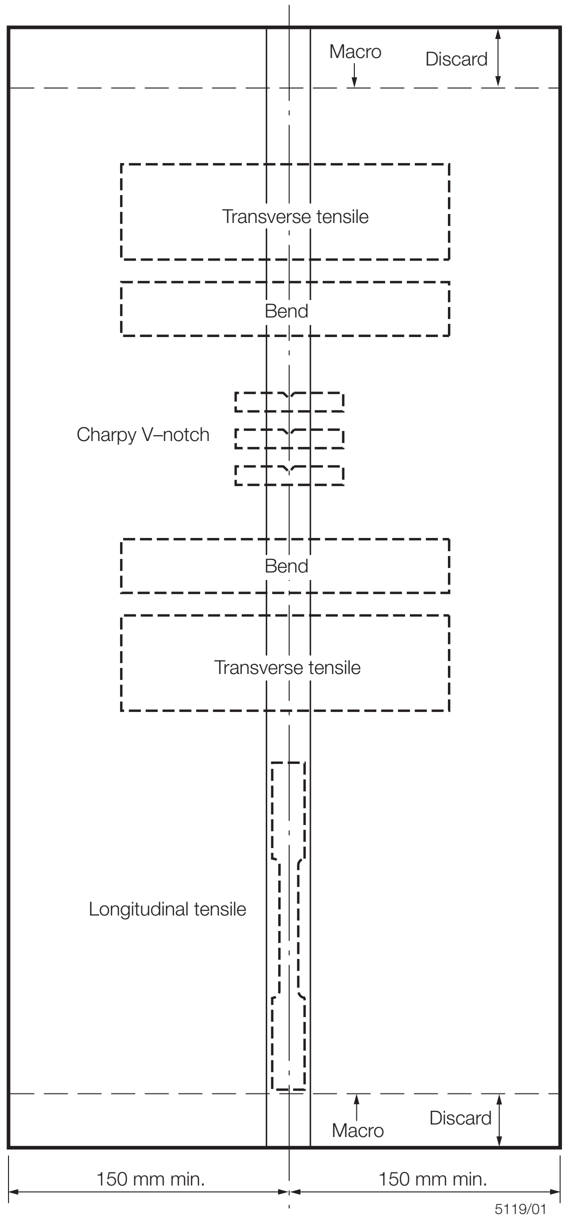


Fig. 11.4.3
Butt weld test assembly (two-run technique)

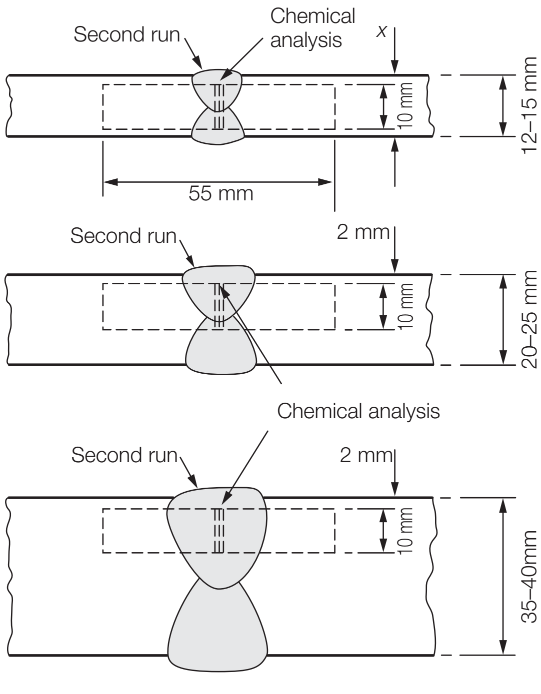


Fig. 11.4.4
Butt weld test assembly (two-run technique): position of impact test specimens

4.6.9 The chemical analysis of the weld metal of the second run in each assembly is to be determined and reported. This is to include the content of all significant elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

4.7 Annual tests

4.7.1 Annual tests are to consist of at least the following:

(a) For wire-flux combinations approved for the multi-run technique, one deposited metal test assembly.

(b) For wire-flux combinations approved for the two-run technique, one butt weld test assembly using plate material 20 to 25 mm in thickness. For Y47 the thickness of plate material may be taken as 50 mm.

4.7.2 The deposited metal assemblies are to be prepared and tested in accordance with 4.3, except that only one longitudinal tensile, three impact test specimens and a chemical analysis are required.

4.7.3 The butt weld test assemblies are to be prepared and tested in accordance with 4.6, except that only one transverse tensile, two bend, three impact test specimens and a chemical analysis are required. One longitudinal tensile test specimen is also to be prepared where the wire-flux combination is approved solely for the two-run technique.

4.7.4 Where a wire-flux combination is approved for welding a range of steels with different specified minimum strength levels, steel of the highest strength approved is to be used for the preparation of the butt weld assembly required by 4.7.1(b).

Section 5
Wires and wire-gas combinations for manual, semi-automatic and automatic welding

5.1 General

5.1.1 Wire-gas combinations and flux-cored or flux-coated wires (for use with or without a shielding gas) are divided into the following categories for the purposes of approval testing:

(a) For use in manual multi-run welding with the inert gas tungsten arc welding process (GTAW).
(b) For use in semi-automatic multi-run metal arc welding.
(c) For use in single electrode multi-run automatic metal arc and GTAW welding.
(d) For use in single electrode two-run automatic metal arc and GTAW welding.

5.1.2 The term 'manual', is used to describe the technique where the gas-shielded tungsten arc torch is held in one hand and the filler is added separately by the other hand.

5.1.3 The term 'semi-automatic' is used to describe processes in which the weld is made manually by a welder holding a gun through which the wire is continuously fed.

5.1.4 In the GTAW process, 'automatic' refers to the fully mechanised control and application of both torch and separate filler wire.

5.1.5 Dependent on the results of mechanical and other tests, approval will be allocated as one of the grades from Table 11.1.1.

5.1.6 A suffix S will be added after the grade mark to indicate approval for semi-automatic multi-run welding.

5.1.7 For wires intended for automatic welding, the suffixes T or M will be added after the grade mark to indicate approval for two-run or multi-run welding techniques, respectively.

5.1.8 For wires intended for both semi-automatic and automatic welding, the suffices will be added in combination.

5.1.9 Solid wire-gas combinations are considered naturally low hydrogen in character and qualify for 'H15' approval without testing. This is not so for cored wires and continuous coated wires which must be tested if there is a need for low hydrogen approval. For the lower strength grades of steel, low hydrogen testing is not normally a requirement for approval. With higher strength steels, it is more important and Table 11.5.1 shows the mandatory minimum low hydrogen status required for approval of wire-gas combinations.

5.1.10 The testing methods to be used for low hydrogen approval are to be in accordance with 3.4, modified to use the manufacturer's recommended welding conditions and adjusting the deposition rate to give a weld deposit weight per sample similar to that deposited when using manual electrodes.

5.1.11 Where applicable, the approved combination will name either the specific gas composition or its trade name, but in either case the composition of the shielding gas is to be reported. Unless otherwise agreed, additional approval tests are required when a shielding gas is used other than that used for the original approval tests. However a wire and gas combination approved with an argon/carbon dioxide shielding gas where the carbon dioxide is between 15-25 per cent is also approved for other combinations of argon/carbon dioxide, provided the carbon dioxide content is within the range 15-25 per cent. The range of approval is limited to ferritic consumables in solid wire, flux cored and coated wire forms and subject to the agreement of the consumable manufacturer and LR.

Table 11.5.1 Minimum low hydrogen approval requirements for wires and wire-gas combinations

Approval grade	'H' grade for m and S techniques	'H' grade for M technique	'H' grade for T technique
1 (1N), 2 (2N), 3 (3N)	NR	NR	NR
1Y, 2Y, 3Y, 4Y	H15 (see Note 2)	NR	NR
2Y40 to 5Y40	H15	H15	NR
2Y47 to 4Y47	H10	H10	H10
3Y42 to 5Y42	H10	H10	H15
3Y46 to 5Y46	H10	H10	H15
3Y50 to 5Y50	H10	H10	H10
3Y55 to 5Y55	H5	H5	H10
3Y62 to 5Y62	H5	H5	H5
3Y69 to 5Y69	H5	H5	H5
1 1/2 Ni	H15	H15	NR
3 1/2 Ni	H15	H15	NR
5 Ni	NR (see Note 3)	NR	NR
9 Ni	NR (see Note 3)	NR	NR

NOTES
1. NR – Not required. Approval may be obtained when requested.
2. Optional in this case. If low hydrogen approval is not obtained, there is a limitation on the carbon equivalent of the steel which is permitted to be welded.
3. Assumes use of an austenitic, non-transformable, filler material.

5.1.12 Wires and wire-gas combinations for multiple electrode automatic welding will be subject to separate approval tests. Any proposals are to be submitted for consideration.

5.1.13 Wires and wire-gas combinations approved with multi-run technique for normal and higher strength levels up to and including ‘Y’ are also considered suitable for welding steels in the three strength levels below that for which they have been approved.

5.1.14 Wires and wire-gas combinations approved with multi-run technique for strength levels Y40 to Y50, but excluding Y47 are also considered suitable for welding steels in two strength levels below that for which they have been approved.

5.1.15 Wires and wire-gas combinations approved with multi-run technique for strength levels Y47, Y55 and above are also considered suitable for welding steels in only one strength level below that for which they have been approved.

5.1.16 Wires and wire-gas combinations with two-run technique approval are not considered suitable for welding steels of any other strength level with that technique, *see* 5.4.1.

5.2 Approval tests for manual and semi-automatic multi-run welding

5.2.1 Approval tests for manual (GTAW) and semi-automatic multi-run welding are to be carried out generally in accordance with the requirements of Section 3, except as required by 5.2, using the respective technique for the preparation of all test assemblies.

5.2.2 Two deposited metal test assemblies are to be prepared in the downhand position as shown in Fig. 11.3.1, one using the smallest diameter, and the other using the largest diameter of wire for which approval is required. Where only one diameter is manufactured, only one deposited metal assembly is to be prepared.

5.2.3 For Y47 grades, as an alternative to Figs. 11.3.1 to 11.3.4, the thickness of the plate used for the test assembly may be taken as 50 mm.

5.2.4 The weld metal is to be deposited according to the practice recommended by the manufacturer, and the thickness of each layer of weld metal is to be between 2 mm and 6 mm, unless it is clearly stated as part of the consumable manufacturer’s published recommendations.

5.2.5 The chemical analysis of the deposited weld metal in each test assembly is to be supplied by the manufacturer and is to include the content of all significant alloying elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

5.2.6 Butt weld assemblies as shown in Fig. 11.3.2 are to be prepared for each welding position for which the wire is to be approved. In the case of approvals for normal and higher strength steels (up to 355 N/mm^2 minimum specified yield strength), tests satisfying the requirements in both the downhand and vertical-upward positions will be considered as having also satisfied the requirements for the horizontal-vertical position. In all other cases, approval in the horizontal-vertical position will require a butt weld to be made in that position and be fully tested.

5.2.7 The downhand assembly is to be welded using, for the first run, wire of the smallest diameter to be approved and, for the remaining runs, wire of the largest diameter to be approved.

5.2.8 Where approval is requested only in the downhand position, an additional butt weld assembly is to be prepared in that position using, if possible, wires of different diameter from those required by 5.2.7. If only one wire diameter is to be approved, this second downhand butt weld should be made using either larger or smaller beads than the first assembly.

5.2.9 The butt weld assemblies, in positions other than downhand, are to be welded using, for the first run, wire of the smallest diameter to be approved, and for the remaining runs, the largest diameter of wire recommended by the manufacturer for the position concerned.

5.2.10 Fillet weld test assemblies as detailed in 3.5 are to be prepared, examined and tested.

5.2.11 Low hydrogen approval tests are to be carried out if required by 5.1.9.

5.2.12 Test specimens from each assembly are to be prepared and tested in accordance with the requirements of 3.2 and 3.3.

5.3 Approval tests for multi-run automatic welding

5.3.1 Approval tests for multi-run automatic welding are to be carried out generally in accordance with the requirements of Section 4, except as required by 5.3, using the multi-run automatic welding technique for the preparation of all test assemblies.

5.3.2 One deposited metal test assembly is to be prepared as shown in Fig. 11.4.1. Welding is to be as detailed in 4.3.4, except that the thickness of each layer is to be not less than 3 mm, unless it is clearly stated as part of the consumable manufacturer’s published recommendations.

5.3.3 For Y47 grades, as an alternative to Figs. 11.4.1 and 11.4.2, the thickness of the plate used for the test assembly may be taken as 50 mm.

5.3.4 One butt weld test assembly is to be prepared as shown in Fig. 11.4.2 for each welding position to be approved for the automatic multi-run technique.

5.3.5 Test specimens from each test assembly are to be prepared and tested in accordance with the requirements of Section 4 for multi-run submerged-arc automatic welding.

5.3.6 Low hydrogen approval tests are to be made if required by 5.1.9.

5.3.7 At the discretion of LR, wires approved for semi-automatic welding in the downhand position may also be approved without additional tests, for use in multi-run automatic welding.

5.4 Approval tests for two-run automatic welding

5.4.1 Approval tests for two-run automatic welding are to be carried out generally in accordance with the requirements of Section 4, except as required by 5.4, using the two-run automatic welding technique for the preparation of all test assemblies. Two butt weld test assemblies are to be prepared and tested using plates of the strength level for which approval is required. Each strength level requires separate approval.

5.4.2 Two butt weld test assemblies are to be prepared generally as detailed in 4.5 and 4.6 using plates 12 to 15 mm and 20 to 25 mm in thickness.

5.4.3 If approval is requested for welding plate thicker than 25 mm, one assembly is to be prepared using plates approximately 20 mm in thickness and the other using plates of the maximum thickness for which approval is requested.

5.4.4 The edge preparation of the test assemblies is to be as shown in Fig. 11.5.1. Small deviations in edge preparation may be allowed, if these form part of the consumable manufacturer's recommendations. For assemblies using plates over 25 mm in thickness, the edge preparation is to be reported for information.

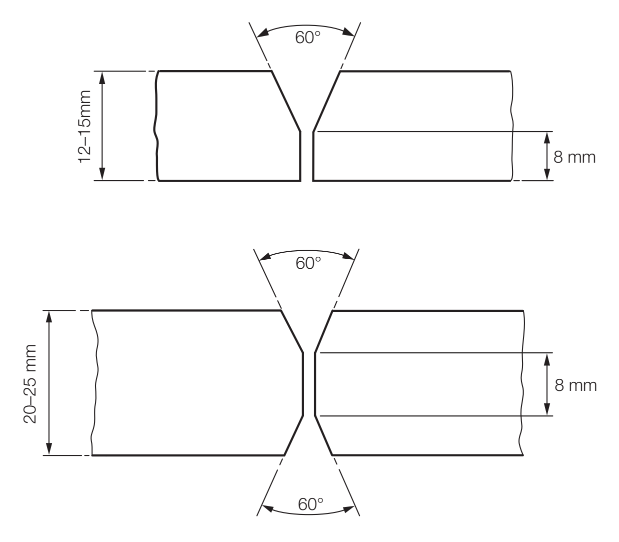


Fig. 11.5.1
Normal edge preparation for two-run butt weld test assemblies

5.4.5 The diameters of wires used are to be in accordance with the recommendations of the manufacturer and are to be reported.

5.4.6 Test specimens from each butt weld assembly are to be prepared and tested in accordance with the requirements of Section 4 for two-run submerged-arc automatic welding.

5.4.7 The weld metal chemical analysis is to be reported as in 4.6.9. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

5.5 Annual tests

5.5.1 Annual tests are to consist of at least the following:

(a) Wires approved for manual welding or semi-automatic welding or either of these combined with approval for automatic multi-run welding:
    one deposited metal test assembly prepared in accordance with 5.2 using a wire of diameter within the approved range.

(b) Wire approved for automatic multi-run welding:
    one deposited metal test assembly prepared in accordance with 5.3 using a wire of diameter as stated in (a).

(c) Wires approved for two-run automatic welding:
    one butt weld test assembly prepared in accordance with 5.4 using plates 20 to 25 mm in thickness or the maximum approved thickness. The diameter of wire used is to be reported.

Section 6
Consumables for use in electro-slag and electro-gas welding

6.1 General

6.1.1 The requirements for the approval of consumables used for electro-slag or electro-gas welding (including consumable nozzles, where applicable) are generally as detailed in Section 4 for two-run submerged-arc welding consumables, except as otherwise detailed in this Section.

6.1.2 For each grade, approval may be restricted for use with specific compositional types of steel. For Grades 1Y, 2Y, 3Y, 4Y, 2Y40, 3Y40 and 4Y40 this will normally be in respect of the grain refining element content, and tests on niobium grain refined steel will normally qualify for use also on steels treated with aluminium or vanadium or combinations of these elements.

6.1.3 Superscript numbers are applied to the 'Y' of higher strength steel consumables, e.g. $2Y^1$, to indicate the type of parent steel for which approval is applicable as follows:

Y^1 approval Grade for higher strength steel is limited to parent steel which has been treated only with aluminium.

Y^2 approval Grade for higher strength steel is appropriate to niobium-treated steels, whether aluminium treated or not. It also covers steels treated only with aluminium.

6.1.4 Each strength level requires separate approval involving the welding and testing of two butt weld assemblies of different thickness. The greater thickness will determine the maximum approved thickness.

6.2 Butt weld test assemblies

6.2.1 Two butt weld test assemblies are to be prepared, one with plates 20 to 25 mm in thickness and the other with plates 35 to 40 mm in thickness. The steel used is not to be of any higher grade (impact toughness) than that for which approval is required. The limitations of 6.1.2 need to be considered in this Section. The chemical composition of the plate, including the content of grain refining elements, is to be reported.

6.2.2 The welding conditions and the edge preparation adopted are to be in accordance with the recommendations of the manufacturer and are to be reported in detail. The manufacturer's maximum recommended gap between plates is to be used in making the test assemblies.

6.2.3 It is recommended that the assemblies are subjected to radiographic examination to identify any defects before the preparation of any test specimens.

6.2.4 Test specimens as follows, and as shown in Fig. 11.6.1, are to be prepared from each test assembly:

(a) Two longitudinal tensile test specimens.
(b) Two transverse tensile test specimens.
(c) Two bend test specimens.
(d) Two macro-sections.
(e) Two sets of three impact test specimens notched in accordance with Fig. 11.6.2.

6.2.5 The chemical analysis of the weld metal in each assembly is to be determined and reported. This is to be supplied by the manufacturer and is to include the content of all significant elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

6.2.6 The results of all transverse tensile and impact tests are to comply with the requirements given in Table 11.4.3 as appropriate. The position of fracture of the transverse tensile test is to be reported. The Charpy V-notch impact test requirements are as for the two-run technique in Table 11.4.3.

6.2.7 The results of all longitudinal tensile tests are to comply with the requirements of Table 11.4.2.

6.2.8 The bend test specimens are to be in accordance with 4.6.7 and Table 11.4.3. Each surface of the weld is to be tested Fension.

6.3 Annual tests

6.3.1 Annual tests are to consist of at least one butt weld test assembly using plate material 20 to 25 mm in thickness.

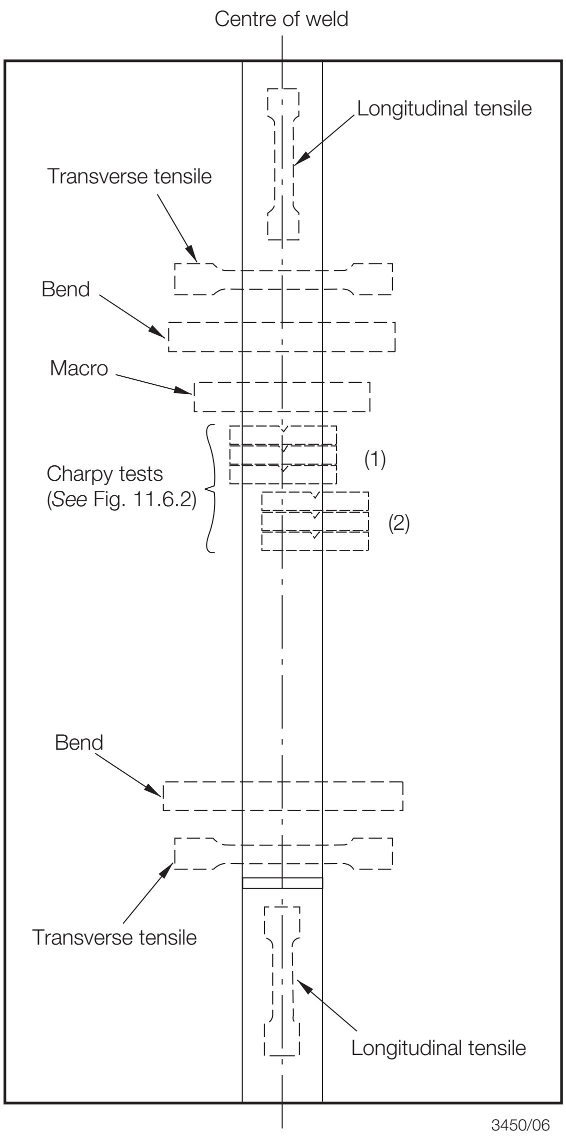
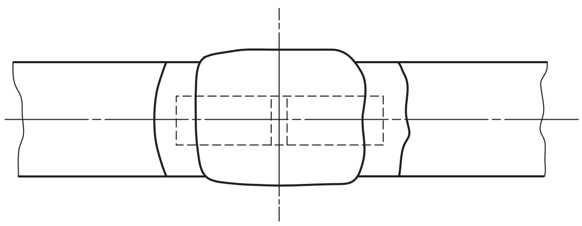


Fig. 11.6.1
Butt weld test assembly for electro-slag or electro-gas welding

6.3.2 The assembly is to be prepared and tested in accordance with 6.2 except that only the following tests are required:

(a) One longitudinal tensile test.
(b) One transverse tensile test.
(c) Two bend tests.
(d) Two sets of three Charpy V-notch impact tests; one set with the notch at the centre of the weld (Position (1) in Fig. 11.6.2), and one set with the notch in the weld metal 2 mm from the fusion line (Position (2) in Fig.11.6.2).
(e) Chemical analysis.
(f) One macro section.

6.3.3 Where a consumable or combination is approved for a range of steels with different specified minimum strength levels, steel of the highest strength level is to be used for the preparation for the assembly required by 6.3.1.



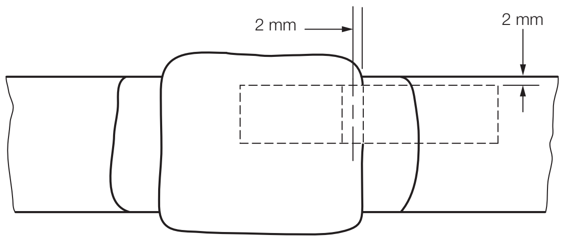


Fig. 11.6.2
Position of Charpy V-notch impact test specimens

Section 7
Consumables for use in one-side welding with temporary backing materials

7.1 General

7.1.1 The requirements for approval of combinations including temporary backing material, for use in one-side welding techniques, are dependent on the technique used and which basic technique it most closely follows. The following are provided for:

(a) Technique m – for manual electrode/backing combinations.
(b) Technique S – for wire-gas/backing combinations used with semi-automatic multi-run technique.
(c) Technique M – for wire-flux or wire-gas in combination with backing material (and maybe supplementary filler materials) used with an automatic multi-run technique.
(d) Technique A – as for M but using a procedure with a high heat input rate (large bead size relative to thickness welded). This would apply to welds made by four or less runs in 20 mm thickness, or eight or less runs in 35 mm.

7.1.2 For technique m, S or M, a single butt weld is to be made in plate of 20–25 mm thickness. For technique A, two butt welds are to be made, one in plate of the maximum thickness recommended by the manufacturer, the other in plate of approximately half the thickness of the first. Usually this will involve thicknesses in the region of 35–40 mm and 20–25 mm respectively.

7.1.3 A wire and gas combination approved with an argon/carbon dioxide shielding gas where the carbon dioxide content is between 15-25 per cent is also approved for other combinations of argon/carbon dioxide, provided the carbon dioxide content is within the range 15-25 per cent. The range of approval is limited to ferritic consumables in solid wire, flux cored and coated wire forms and subject to the agreement of the consumable manufacturer and LR.

7.1.4 Any unrecognised techniques or unusual combinations will be considered for approval subject to a test programme to be agreed based on the details of the technique and combination which are to be submitted in advance.

7.1.5 Where low hydrogen approval is required either by Table 11.7.1 or by the manufacturer, it should be noted that this will generally be achieved through separate testing of:

(a) the backing material, and
(b) the welding electrode or combination of wire-flux or wire-gas.

7.1.6 The hydrogen potential of the backing material is to be determined using the modified Gayley-Wooding method which expresses the total hydrogen content as water by weight per cent. The qualifying levels are:

To qualify as:	H_20 g/100g sample
H15	0,5
H10	0,3
H5	0,2

7.1.7 The sampling and approval of the combinations without the backing are to follow the general requirements of Sections 3, 4 or 5, as appropriate.

7.1.8 Combinations approved with multi-run technique (m, S and M) for normal and higher strength levels up to and including 'Y' are also considered suitable for welding steels in the three strength levels below that for which they have been approved.

7.1.9 Combinations approved with multi-run technique (m, S and M) for strength levels Y40 to Y50, but excluding Y47, are also considered suitable for welding steels in two strength levels below that for which they have been approved.

7.1.10 Combinations approved with multi-run technique (m, S and M) for strength levels Y47, Y55 and above are also considered suitable for welding steels in only one strength level below that for which they have been approved.

7.1.11 Combinations approved for the 'A' multi-run technique are not considered suitable for welding steels of any other strength level with that technique.

Table 11.7.1 Minimum low hydrogen approval requirements for one-side welding with combinations including temporary backing material

Approval grades	'H' grade for m and S techniques	'H' grade for M technique	'H' grade for A technique
1 (1N), 2 (2N), 3 (3N)	NR	NR	NR
1Y, 2Y, 3Y, 4Y	H15 (*see* Note 2)	NR	NR
2Y40 to 5Y40	H15	H15	NR
2Y47 to 4Y47	H10	H10	H15
3Y42 to 5Y42	H10	H10	H15
3Y46 to 5Y46	H10	H10	H15
3Y50 to 5Y50	H10	H10	H10
3Y55 to 5Y55	H5	H5	H10
3Y62 to 5Y62	H5	H5	H5
3Y69 to 5Y69	H5	H5	H5
$1^1/_2$ Ni	H15	H15	NR
$3^1/_2$ Ni	H15	H15	NR
5 Ni (*see* Note 3)	NR	NR	NR
9 Ni (*see* Note 3)	NR	NR	NR

NOTES
1. NR – Not required. Approval may be obtained when requested.
2. Optional in this case. If low hydrogen approval is not obtained, there is a limitation on the carbon equivalent of the steel which is permitted to be welded.
3. Assumes the use of an austenitic, non-transformable, filler material.

7.2 Approval tests for manual (m), semi-automatic (S) and automatic multi-run (M) techniques

7.2.1 For each position to be approved, one butt weld assembly is to be prepared using plates of 20–25 mm thickness as shown in Fig. 11.7.1. The grade of plate used is to be no higher in toughness than that for which approval is required. The strength is to be appropriate to the grade for which welding approval is requested.

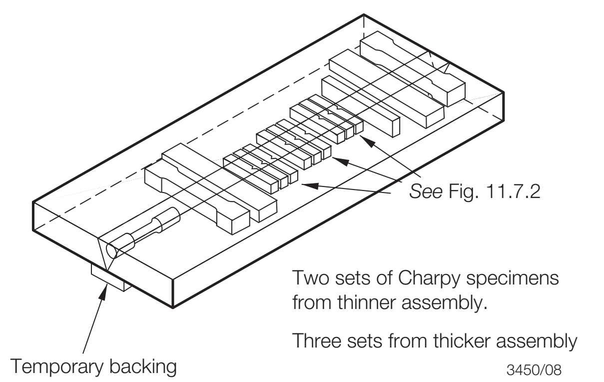


Fig. 11.7.1 Butt weld test assembly and specimens for all techniques

7.2.2 The thickness of test assembly is to be 50 mm for Y47 base material.

7.2.3 The edge preparation and welding conditions are to be in accordance with the recommendations of the manufacturers.

7.2.4 Test specimens are to be prepared as shown in Fig. 11.7.1 and Fig. 11.7.2(a):
(a) One longitudinal tensile test specimen (from the centre of the weld).
(b) Two transverse tensile specimens.
(c) Two bend test specimens, one with the face in tension, the other with the root in tension.
(d) One macrosection.
(e) Two sets of three Charpy impact test specimens positioned and notched in accordance with Fig.11.7.2(a).

7.2.5 The results of all transverse tensile, bend and impact tests are to comply with the requirements in Table 11.3.3 for m and S technique, and Table 11.4.3 for M technique. The position of fracture of the transverse tensile test is to be reported. The appearance of the bend test specimens is to be in accordance with 3.3.13.

7.2.6 The results of all longitudinal tensile tests are to comply with the requirements in Table 11.3.2.

7.2.7 Low hydrogen approval is required in accordance with Table 11.7.1.

7.2.8 Chemical analyses are to be made and reported from positions corresponding to the weld metal in the upper and lower Charpy specimens of the downhand butt weld. These are to be supplied by the manufacturer and are to include the content of all significant elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

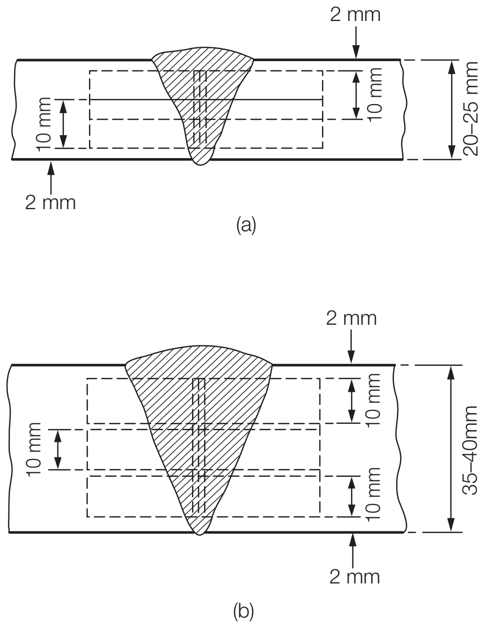


Fig. 11.7.2
Position of Charpy V-notch impact tests for one-side automatic welding

7.3 Approval tests for high heat input automatic (A) techniques

7.3.1 Two butt weld assemblies are to be prepared, usually one of 35–40 mm thickness, the other 20–25 mm, as shown in Fig. 11.7.1, noting that in the thinner assembly only two sets of Charpy specimens are required. The grade of plates used is to be no higher in toughness than that for which approval is required. The strength is to be appropriate to the grade for which welding approval is requested.

7.3.2 For Y47 grade, the thicker assembly is to be prepared from the maximum thickness for which approval is required, and the thinner assembly is to be prepared from 50 mm thickness. Where approval is required for 50 mm thickness, only one assembly from that thickness is required.

7.3.3 The edge preparation and welding conditions are to be in accordance with the manufacturer's recommendations, and are to be reported to LR.

7.3.4 Test specimens as follows are to be prepared as shown in Fig. 11.7.1 and Figs. 11.7.2(a) and (b):

(a) One longitudinal tensile test specimen (from centre of weld).
(b) Two transverse tensile test specimens.
(c) Two bend test specimens.
(d) One macro-section.
(e) From assembly 20 to 25 mm thick, two sets of three impact test specimens positioned and notched in accordance with Fig. 11.7.2(a).
(f) From assembly 35 to 40 mm thick, three sets of three impact test specimens positioned and notched in accordance with Fig. 11.7.2(b).
(g) From assembly of thickness 50 mm or more, three sets of three impact test specimens positioned and notched in accordance with Fig. 11.7.2(b). The second set positioned in the mid-thickness of test assembly.
The bend specimens are to be tested, one with the face in tension, the other with the root in tension.

7.3.5 The results of all transverse tensile, bend and impact tests are to comply with the requirements of Table 11.4.3. The appearance of the bend test specimens is to be in accordance with 3.3.13. The Charpy V-notch impact test requirements are as for the two-run technique in Table 11.4.3.

7.3.6 The results of all longitudinal tensile tests are to comply with the requirements in Table 11.3.2, except that for Grades 1Y, 2Y and 3Y the tensile strength is to be not less than 490 N/mm^2.

7.3.7 Low hydrogen approval is required in accordance with Table 11.7.1.

7.3.8 Chemical analyses are to be made and reported from positions corresponding to the weld metal in the uppermost and lowest Charpy specimens in the thicker plate weld. This is to be supplied by the manufacturer and is to include the content of all significant elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

7.4 Annual tests

7.4.1 Annual tests are to consist of, at least, one butt weld test assembly, for each technique approved, using plates of 20 to 25 mm thickness.

7.4.2 The assembly is to be prepared and tested in accordance with 7.2 or 7.3, as appropriate, except that only the following tests are required:

(a) One longitudinal tensile test (from centre of weld).
(b) One transverse tensile test.
(c) Two bend tests.
(d) One set of three impact tests taken from the root of the weld and the specimens notched in accordance with Fig. 11.7.2.
(e) Chemical analysis (one only).

■ *Section 8*
Consumables for welding austenitic and duplex stainless steels

8.1 General

8.1.1 Tests for the approval of consumables intended for welding the austenitic and duplex stainless steels detailed in Ch 3,7 are to be carried out generally in accordance with the Section (3, 4, 5, 6 or 7) relevant to the type of consumable or combination.

8.1.2 Approval will be indicated by the grade or grades of parent stainless steel for which the consumable or combination is approved.

8.1.3 Where a shielding gas is employed, separate approval will be required for each specific shielding gas composition.

8.1.4 Consumables for welding the austenitic stainless steels and the duplex stainless steels to carbon or carbon-manganese steels will be approved in a similar manner. Parent plate used for the butt and fillet weld test assemblies will be carbon or carbon-manganese steel with either austenitic stainless steel or duplex stainless steel, as appropriate. Approval will be indicated by 'SS/CMn' and 'Dup/CMn' respectively, however, no buttering of test assembly plates is allowed for these two approvals.

8.1.5 Separate approval will be given for welding chemical and cryogenic applications. For chemical use, evidence of relevant corrosion resistance will be required. Charpy impact toughness tests will be required for all uses, but for cryogenic use the Charpy impact toughness requirements are more severe.

8.1.6 The welding technique will be indicated in the approval grading by a letter:

- m – for manual SMAW or GTAW welding.
- S – for wire-gas combinations used with a semi-automatic multi-run technique.
- M – for wire-flux or wire-gas combinations used with an automatic multi-run technique.
- T – for wire-flux or wire-gas combinations used with an automatic two-run technique.
- A – as for M but using a procedure with a high heat input rate (large bead size relative to thickness welded). This would apply to welds made by four or less runs in 20 mm thickness, or eight or less runs in 35 mm.

8.2 Deposited metal test assemblies

8.2.1 Where the relevant Section requires deposited metal assemblies to be made and tested, the plates used must be either of the type for which approval is required or of normal strength carbon, or carbon-manganese steel with the prepared edges built up with stainless steel weld metal and finished with a layer of weld metal from the consumable to be approved.

8.2.2 The chemical analysis of the deposited weld metal is to be reported, including all significant elements. The elements reported will be dependent on the type of stainless steel for which approval of the consumables is requested. Any unusual weld metal compositions will have to be justified in respect of the particular approval requested. This is to be supplied by the manufacturer and is to include the content of all significant elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

8.2.3 The results of all tensile and notch impact tests are to comply with the requirements given in Table 11.8.1 as appropriate.

8.2.4 The ferrite content in the last weld run from each deposited metal assembly is to be determined by physical or metallographic means, and reported, indicating the method of determination.

Table 11.8.1 Requirements for deposited metal tests (manual, semi-automatic and automatic multi-run techniques)

Grade	0,2% proof stress N/mm² minimum	1% proof stress N/mm² minimum	Tensile strength N/mm² minimum	Elongation on 50 mm % minimum	Charpy V-notch impact tests		
					Chemical test temperature °C	Cryogenic test temperature °C	Average energy *See* Note 1 J minimum
304L	270	310	500	25	–20	–196	29
304LN	305	345	530	22	–20	–196	29
316L	270	310	500	22	–20	–196	29
316LN	305	345	530	22	–20	–196	29
317L	305	345	530	22	–20	–196	29
317LN	340	380	570	22	–20	–196	29
321	290	330	550	22	–20	–196	29
347	290	330	550	22	–20	–196	29
S 31254	370	410	650	22	–20	–196	29
N 08904	270	310	500	22	–20	–196	29
SS/CMn	270	310	500	22	–20	–60	29
S 31260	485	525	690	20	–20	*see* Note 2	40
S 31803	450	490	620	25	–20		40
S 32550	550	590	760	15	–20		40
S 32750	550	590	800	15	–20		40
S 32760	550	590	750	25	–20		40
Dup/CMn	270	310	500	22	–20	*see* Note 2	40

NOTES
1. Energy values from individual impact test specimens are to comply with 1.4.3.
2. Approval for cryogenic applications is to be obtained at the procedure approval stage.

8.3 Butt weld test assemblies

8.3.1 Where the relevant Section requires butt weld assemblies to be made and tested, the plates used are to be either of the type for which approval is required or of steel having strength and ductility within the range specified for the grade to be approved. In the latter case, provided the consumable is metallurgically compatible with the base material to be used, the prepared edges are to be built up with a layer of weld metal before final machining of the weld preparation.

8.3.2 The results of transverse tensile, notch impact and bend tests are to comply with the requirements of Table 11.8.2 as appropriate. The position of fracture is to be reported to LR.

8.3.3 The ferrite content at the centre of the weld metal in each butt weld assembly is to be determined by physical or metallographic means, and meet the requirements in Table 11.8.2. The method of determination is to be reported.

8.3.4 For austenitic and duplex stainless steel approvals (except for types 304L, 316L, 321 and 347), an appropriate sample from each butt weld assembly is to be submitted to the corrosion testing provided in ASTM G48, Method 'C'. The results are to be reported so as to allow confirmation of the maximum acceptable pitting corrosion resistance temperature. This will be part of the approval grading and will be set at 5°C intervals. The minimum pitting corrosion temperature would not be expected to be less than 20°C.

8.4 Fillet weld test assemblies

8.4.1 Where the relevant Section requires fillet weld assemblies to be made and tested, the plates used must be either of the type for which approval is required or of steel having strength and ductility within the range specified for the grade to be approved. In the latter case, the surfaces on which the fillet weld beads are to be deposited are to be cut back by machining and then built up to original dimensions with weld metal from the consumable to be approved.

8.4.2 The ferrite content at the centre of the weld metal in each fillet weld bead of each assembly is to be determined from the centre macro-section by physical or metallographic means, and reported. The method of determination is also to be reported to LR.

8.4.3 Where approval is sought for fillet welding only, corrosion testing is to be carried out in accordance with 8.3.4 from a sample taken from the deposited metal test assembly.

8.5 Annual tests

8.5.1 Annual tests are to be carried out as required by the relevant Section appropriate to the type of consumable and welding technique. The tests are to include a weld ferrite content in accordance with 8.2.4 or 8.3.3 as appropriate.

8.5.2 The results of all tests are to comply with the requirements given in Table 11.8.1 and Table 11.8.2 as appropriate.

Table 11.8.2 Requirements for butt weld tests (all techniques)

Grade	Tensile strength N/mm^2 minimum	Bend test ratio: $\frac{D}{t}$	Weld ferrite content %	Charpy V-notch impact tests: Chemical test temperature °C	Charpy V-notch impact tests: Cryogenic test temperature °C	Charpy V-notch impact tests: Average energy (*see* Note 1) J minimum
304L	500	3	4–12	–20	–196	27
304LN	530	3	4–12	–20	–196	27
316L	500	3	4–12	–20	–196	27
316LN	530	3	4–12	–20	–196	27
317L	530	3	4–12	–20	–196	27
317LN	570	3	4–12	–20	–196	27
321	550	3	4–12	–20	–196	27
347	550	3	4–12	–20	–196	27
S 31254	650	3	(*see* Note 2)	–20	–196	27
N 08904	500	3	(*see* Note 2)	–20	–196	27
SS/CMn	500	3	4–12	–20	–60	27
S 31260	690	4	35–65	–20	(*see* Note 3)	40
S 31803	620	3	35–65	–20		40
S 32550	760	6	35–65	–20		40
S 32750	800	6	35–65	–20		40
S 32760	750	6	35–65	–20		40
Dup/CMn	500	3	(*see* Note 2)	–20	(*see* Note 3)	40

NOTES
1. Energy values from individual impact test specimens are to comply with 1.4.3.
2. To be reported for special consideration.
3. Approval for cryogenic applications is to be obtained at the procedure approval stage.

Section 9 Consumables for welding aluminium alloys

9.1 General

9.1.1 Tests for the approval of consumables intended for welding the aluminium alloys detailed in Chapter 8 are to be carried out generally in accordance with the requirements of Sections 1, 2 and 5, except as otherwise detailed in this Section.

9.1.2 Approval will be indicated by the grade shown in Table 11.9.1. Plate of the corresponding type of aluminium alloy and of appropriate thickness is to be used for the preparation of the weld test assemblies, and may be of any temper listed in LR Rules.

Table 11.9.1 Requirements for butt weld tests

Consumable Approval Grade (*see* Note 1)	Base material used for the test	Tensile strength N/mm^2 minimum	Bend test ratio $\frac{D}{t}$
LR RA/LR WA	5754	190	3
LR RB/LR WB	5086	240	6
LR RC1/LR WC1	5083	275	6
LR RC2/LR WC2 (*see* Note 2)	5383 or 5456	290	6
LR RC3/LR WC3 (*see* Note 2)	5059	330	6
LR RD/LR WD (*see* Note 4)	6005A 6061 6082	170 170 170	6 6 6

NOTES
1. The prefixes ‘R’ and ‘W’ indicate ‘rod’ form (for Gas Tungsten Arc Welding (GTAW)) or ‘wire’ form (for Gas Metal Arc Welding (GMAW) and GTAW).
2. Approval of grade LR RC2/LR WC2 confers approval of 5383, 5456 and 5083 base material grade.
3. Approval of grade LR RC3/LR WC3 confers approval of 5059, 5383, 5456 and 5083 base material grades.
4. Approval of grade LR RD/LR WD confers approval of 6005A, 6061 and 6082 base material grades.

9.1.3 The welding technique will be indicated in the approval grading by a letter:
- m – manual multi-run welding (GTAW),
- S – semi-automatic multi-run welding (GMAW),
- M – automatic multi-run welding (GTAW or GMAW),
- T – automatic two-run welding (GMAW).

9.1.4 The compositions of the shielding gas and the filler/electrode wire are to be reported.

9.1.5 Approval granted using the multi-run technique for a specific filler/electrode wire with a gas in one of the groups listed in Table 11.9.2 will extend to any other gas compositions within that same group, provided that the gas composition is within the range recommended by the consumable manufacturer, subject to agreement with LR.

Table 11.9.2 Shielding gas compositions

Group	Gas composition (Vol. %) (*see* Note)	
	Helium	Argon
I-1	–	100
I-2	100	–
I-3	>0 ≤33	Remainder
I-4	>33 ≤66	Remainder
I-5	>66 ≤95	Remainder
S	Special gas	

NOTE
Gases of other composition (mixed gases) or special purity may be considered as special gases and will require separate approval tests.

9.1.6 Approval granted for the two-run technique will be for a specific shielding gas composition; additional tests may be required if a change in shielding gas composition is sought.

9.1.7 On completion of welding, assemblies are to be allowed to cool naturally to ambient temperature. Welded test assemblies and test specimens are not to be subjected to any heat treatment after welding except for the alloy Grades 6005A, 6061 and 6082. These are to be allowed to naturally age at ambient temperature for a period of 72 hours from the completion of welding, before testing is carried out. A second solution heat treatment is not permitted.

9.1.8 All butt test assemblies are to be subjected to both radiographic and visual examination and imperfections such as lack of fusion, lack of penetration, cavities, inclusions, pores and cracks assessed in accordance with Intermediate Level C of ISO 10042, aided where necessary by dye penetrant and ultrasonic examination.

9.1.9 Fillet weld test assemblies and macro-sections are to be visually examined for imperfections, such as lack of fusion, lack of penetration, cavities, inclusions, pores and cracks, in accordance with Intermediate Level C of ISO 10042, aided where necessary by radiographic and dye penetrant examination.

9.2 Approval tests for manual, semi-automatic and automatic multi-run techniques

9.2.1 Plate of the corresponding type of aluminium alloy and of appropriate thickness is to be used for the preparation of the weld test assemblies.

9.2.2 The welding parameters are to be within the range recommended by the manufacturer and are to be reported.

9.2.3 Welded assemblies are to be prepared and tested in accordance with 9.3, 9.4 and 9.5.

9.3 Deposited metal test assembly

9.3.1 One assembly is to be prepared in the downhand position as shown in Fig. 11.9.1.

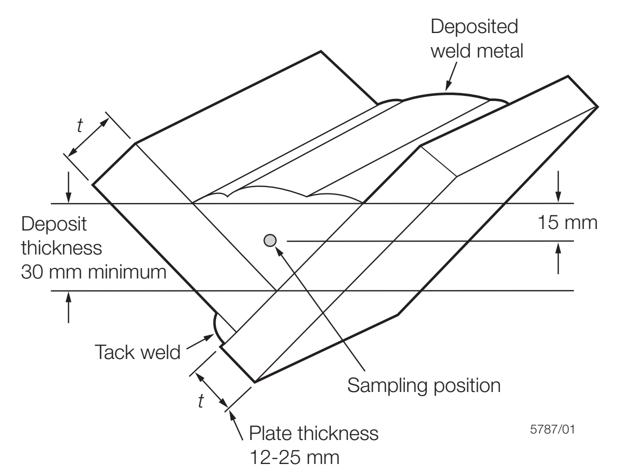


Fig. 11.9.1 Deposited metal test assembly

9.3.2 The chemical composition of the plate used for the assembly is to be compatible with the weld metal.

9.3.3 The thickness of the plate used, and the length of the assembly, are to be appropriate to the welding process. The plate thickness is to be not less than 12 mm.

9.3.4 For the approval of filler wire/gas and electrode wire/gas combinations for manual or semi-automatic welding by GTAW or GMAW, one test assembly is to be welded using any size of wire within the range for which approval is sought.

9.3.5 For automatic multi-run approval, one test assembly is to be welded by the respective process using the recommended diameter of wire.

9.3.6 The weld metal is to be deposited in multi-run layers in accordance with normal practice. The direction of deposition of each layer is to alternate from each end of the plate.

9.3.7 The deposited weld metal in the assembly is to be analysed and reported including the contents of all significant elements. The elements reported will be dependent on the type of aluminium alloy for which approval of the consumables is requested. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

9.4 Butt weld test assemblies

9.4.1 Plate of the corresponding type of aluminium alloy and of an appropriate thickness is to be used for the preparation of the test assemblies.

9.4.2 In order to ensure sound and representative welds, it is essential that test assemblies are cleaned and degreased prior to welding. Assemblies as shown in Fig. 11.9.2 are to be prepared for each welding position (downhand, horizontal-vertical, vertical-upward, vertical-downward, and overhead) for which the consumable is recommended by the manufacturer; except that consumables satisfying the requirements for downhand and vertical-upward positions will be considered as also complying with the requirements for the horizontal-vertical position. Any wire diameter(s) to be approved may be used.

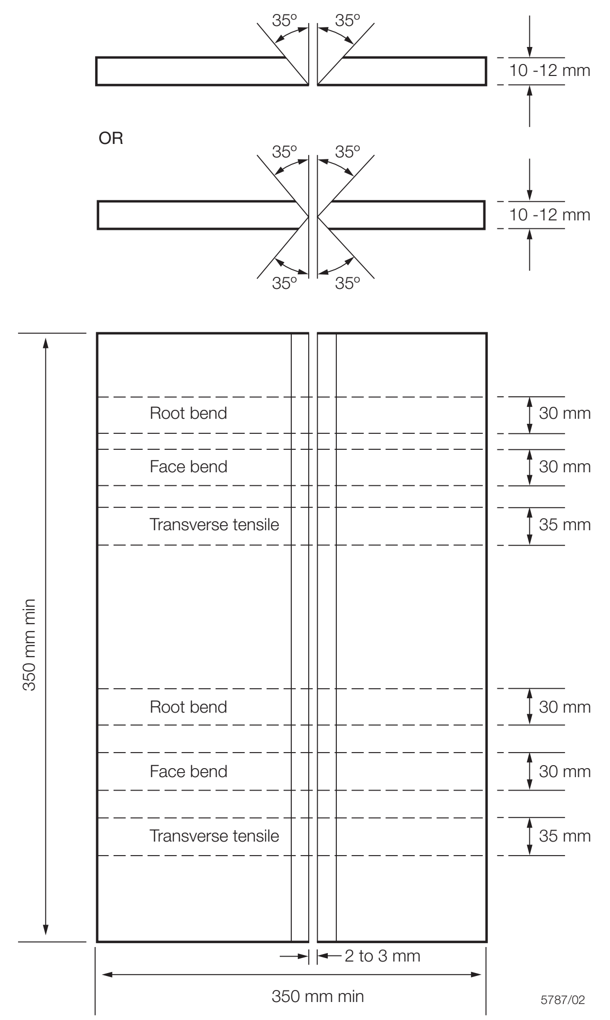


Fig. 11.9.2
Butt weld test assembly
(positional, multi-run technique)

9.4.3 One assembly, as shown in Fig. 11.9.3, is to be prepared for welding in the downhand position. The assembly is to be welded using, for the first run, wire of the smallest diameter recommended by the manufacturer and, for the remaining runs, wire of the largest diameter to be approved.

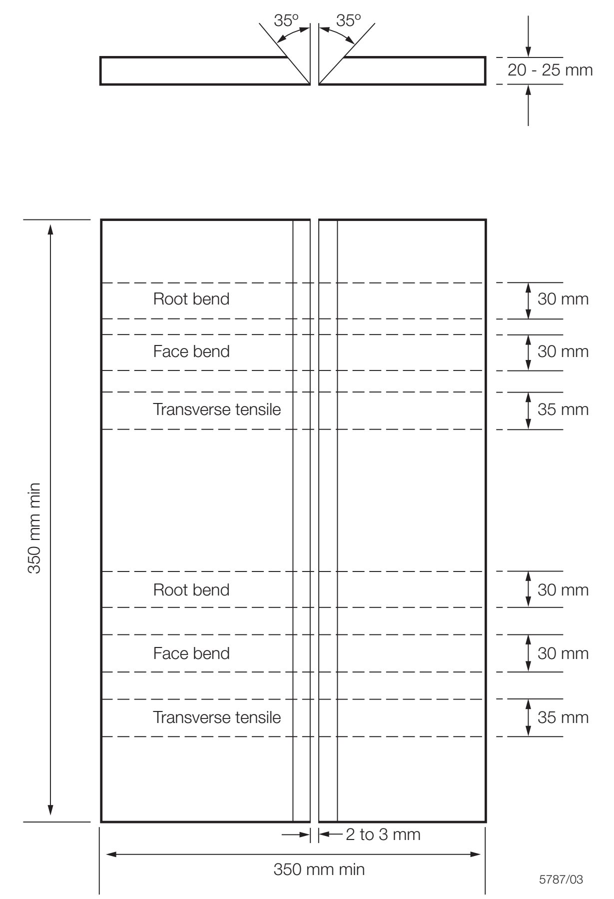


Fig. 11.9.3
Butt weld test assembly
(downhand, multi-run technique)

9.4.4 The welding conditions are to be in accordance with the recommendations of the manufacturer and are to be reported in detail.

9.4.5 The welded assemblies are to be subjected to NDE. Imperfections are to be assessed in accordance with 9.1.8.

9.4.6 The test specimens are to be taken from the welded assemblies as shown in Fig. 11.9.2 and Fig. 11.9.3. For each assembly they are to comprise:

- 2 transverse tensile specimens;
- 2 face bend specimens; and
- 2 root bend specimens.

9.4.7 All tensile test specimens are to have a tensile strength not less than the respective value shown in Table 11.9.1. The position of each fracture is to be reported.

9.4.8 The bend test specimens are to be bent around a former having a diameter not more than the number of times the thickness of the test specimen, as shown in Table 11.9.1, and can be considered as complying with the requirements if, after bending to an angle of not less than 180°, no crack or other open defect exceeding 3 mm in length can be seen on the outer surface. Flaws appearing at the corners of a test specimen may be ignored.

9.4.9 In order to obtain uniform bending of the bend test specimens, it is recommended that the wrap-around or guided bend test using a roller method is employed.

9.5 Fillet weld test assembly

9.5.1 When approval is being sought for both butt and fillet welding, one assembly is to be prepared and welded in the horizontal-vertical position and tested in accordance with the appropriate requirements of 3.5, except that the plates are to be of an aluminium alloy compatible with the weld metal, that no hardness tests are required and that for automatic multi-run approval only one fillet weld bead is to be made using the recommended wire diameter. In this case, the bead size is to be as large as the maximum single bead size recommended by the manufacturer for fillet welding.

9.5.2 When approval is being sought for fillet welding only, one assembly is to be prepared and welded in each position for which approval is sought, and tested as detailed in 9.5.1.

9.5.3 The results of examination of the macro-specimens and the fractured fillet welds are to be reported in accordance with 3.5.4 and 3.5.6. Imperfections are to be assessed in accordance with 9.1.9.

9.6 Approval tests for two-run technique

9.6.1 Two butt weld test assemblies are to be prepared using the following plate thicknesses:

(a) one with the maximum thickness for which approval is requested; and
(b) one with a thickness approximately one half to two thirds that of the maximum thickness.

9.7 Butt weld test assemblies (two-run technique)

9.7.1 The plates used are to be of the aluminium alloy appropriate to the approval required as shown in Table 11.9.1. The composition of the plate material is to be within the range specified for that alloy in Table 8.1.2 in Chapter 8 and is to be reported including all significant elements.

9.7.2 The wire diameter, edge preparation, welding current, arc voltage and travel speed are to be in accordance with the manufacturer's recommendations and are to be reported.

9.7.3 Each butt weld is to be made in two runs, one from each side. After completion of the first run, the assembly is to be left in still air until it has cooled to less than 50°C.

9.7.4 The welded assemblies are to be subjected to NDE. Imperfections are to be assessed in accordance with 9.1.8.

9.7.5 The test specimens as shown in Fig. 11.9.4 are to be prepared from each test assembly. The edges of the discards are to be polished and etched, and must show complete fusion and inter-run penetration of the welds. Each cut in the assembly is also to be examined to confirm that complete fusion and penetration have been achieved.

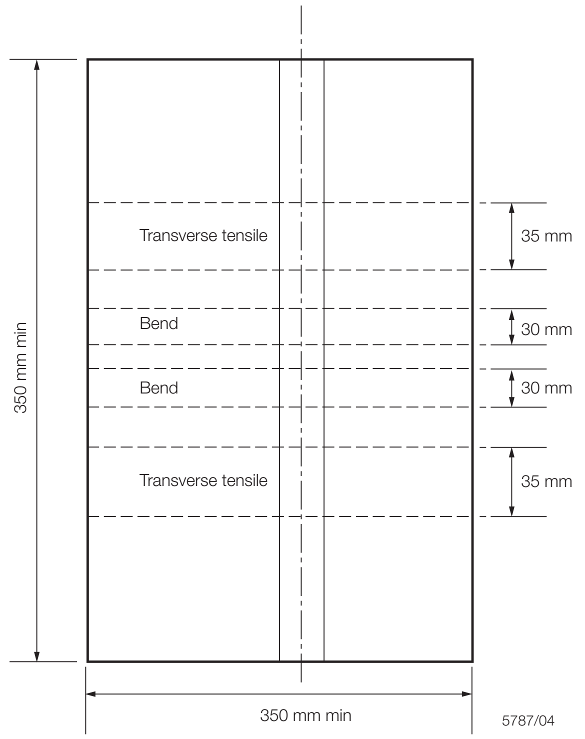


Fig. 11.9.4
Butt weld test assembly (two-run technique)

9.7.6 The results of the transverse tensile tests are to be as in 9.4.7 and of the bend tests as in 9.4.8. The position of the fracture in each transverse tensile specimen is to be reported.

9.8 Annual tests

9.8.1 Annual tests are to consist of the following:

(a) for combinations approved for the multi-run technique, one deposited metal assembly in 9.3 and one downhand butt assembly in 9.4;

(b) for combinations approved for the two-run technique, one butt weld assembly in plate material of thickness equal to one half to two thirds that of the maximum thickness approved.

9.8.2 For the automatic two-run technique, one butt weld assembly is to be prepared and tested in accordance with 9.7.

Welding Qualifications

Section

■ *Section 1* General qualification requirements

1.1 General

1.1.1 This Section applies to all welding qualifications and tests required to be performed in the course of new construction, conversions, modifications or repairs made on ships, other marine structures and their associated pressure vessels, machinery and equipment.

1.1.2 These Rules also apply to all welding work related to other applications for which Lloyd's Register (hereinafter referred to as LR) have issued Rules or have an interest.

1.1.3 It is the responsibility of the manufacturer to ensure compliance with all aspects of these Rules. All deviations are to be recorded as non-compliances and brought to the attention of the Surveyor along with the corrective actions taken. Failure to do this is considered to render the welding tests as not complying with the Rules.

1.1.4 Welding tests are to be performed under survey at the manufacturer's works. Welding procedure qualification tests and welder qualifications tests are to be performed and approved prior to commencement of fabrication or construction.

1.1.5 Weld procedure tests made in accordance with EN, ISO, JIS, ASME or AWS may be considered for acceptance provided that, as a minimum, they are equivalent to and meet the technical intent of these Rules to the satisfaction of the Surveyor.

1.1.6 Welding tests that have previously been carried out may be considered for acceptance, provided that they have been supervised by an independent body acceptable to LR and the Surveyor is satisfied with the authenticity of such tests.

1.1.7 The responsibility for the performance of the weld tests rests with the manufacturer. Aspects of the welding tests, such as mechanical testing, non-destructive testing and heat treatment, may be subcontracted by the manufacturer provided that the subcontractor performs the work under the technical control and direction of the manufacturer, and this is agreed with the Surveyor prior to commencing the work.

1.1.8 In these Rules, the term 'manufacturer' is considered to include any firm or organisation that performs welding and is considered to be the shipbuilder, or construction firm, or fabricator, or material manufacturer.

1.2 Design

1.2.1 Welding procedure qualification tests are required to give assurance that construction welds made in accordance with the approved plans or the approved design have acceptable properties. It is the manufacturer's responsibility to establish and document whether a procedure is suitable for a particular application.

1.2.2 The requirements relate to mechanical properties of the weld and heat affected zone, however, other tests may be required on certain materials, for example, corrosion or fatigue tests, in order to ensure suitability for the proposed application.

1.3 Materials

1.3.1 Materials used for testing are to be of the same grade, type and from the same manufacturing process as those to be used for construction, unless prior agreement is obtained from the Surveyor. Such agreements will only apply on a case-by-case basis.

1.3.2 All materials used for testing are to be suitably marked and identifiable to the original manufacturer's material certificate.

1.4 Performance of welding tests

1.4.1 All welding and subsequent testing is to be performed in accordance with the requirements of this Chapter.

1.4.2 The manufacturer is responsible for monitoring the tests and for recording all the welding variables as specified in 2.2 and for compiling all the non-destructive examination (NDE) reports and mechanical test records for submission to the Surveyor.

1.4.3 The laboratory or testing establishment used to perform the tests is to have the necessary equipment, maintained in good order and suitably calibrated. The Surveyor is to be satisfied that the laboratory personnel have the appropriate skills and are appropriately qualified in accordance with Ch 2,1.2.1.

Section 2 Welding Procedure Qualification Tests for Steels

2.1 General

2.1.1 The requirements of this Section relate to welding procedure test requirements of carbon, carbon-manganese steels and low alloys steels. Additional requirements for austenitic and austenitic/ferritic duplex stainless steels, aluminium and copper alloys are specified in Sections 3 and 4 respectively.

2.1.2 Prior to performing the welding procedure qualification test, the manufacturer is to present to the Surveyor a preliminary Welding Procedure Specification (pWPS) detailing the welding processes, positions, joint types, materials and heat treatments to be performed during the test. The pWPS is to be presented for information prior to commencing the test.

2.1.3 The type and extent of testing to be applied to each welding procedure test is to be in accordance with subsequent Sections of this Chapter.

2.1.4 For the welding procedure approval, the welding procedure qualification tests given in this Section are to be carried out with satisfactory results. Welding procedure specifications are to refer to the test results achieved during welding procedure qualification testing.

2.2 Welding variables

2.2.1 In order that the conditions of the qualification test may be applied to production welding operations, the appropriate variables are to be recorded by the manufacturer during welding and testing from the following list:

(a) The unique qualification reference number and the date of welding;
(b) The material type, grade, product form, dimensions and identification;
(c) Welding process(es), including tack welds;
(d) Joint type, dimensions and surface condition;
(e) Welding position(s);
(f) Welding technique(s), weaving, multiple electrodes, etc;
(g) Welding consumables including fluxes, shielding gases, etc;
(h) Control of consumables, baking or drying conditions, etc;
(j) Welding parameters, current, voltages, travel speeds, etc;
(k) Number and sequence of weld runs;
(l) Backing materials including any backing gas;
(m) Preheats and interpass temperatures;
(n) Methods used for cleaning and inspection of root deposits;
(o) Post-weld heat treatment, temperature and cycle times;
(p) Special weld profiling requirements.

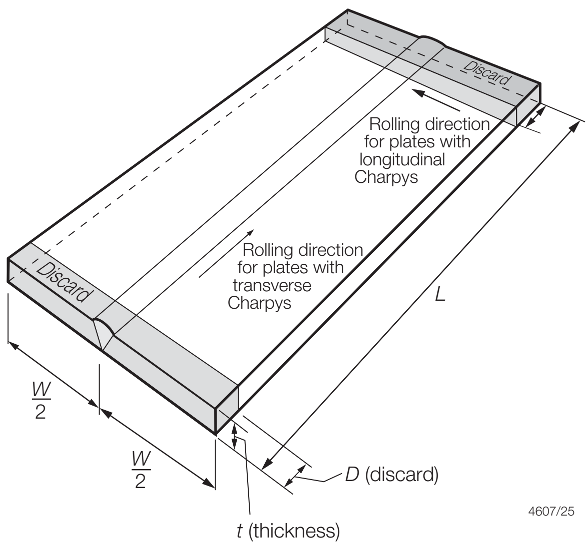
2.2.2 Other variables may need to be recorded depending on the particular welding process or application and are to be agreed with the Surveyor, for example the peak and base current and cycle times for pulse welding, electrode type and nozzle size for GTAW welding, etc.

2.3 Steel test assemblies

2.3.1 Tests are to be performed using the welding process and positions anticipated for actual construction. The weld test assemblies are to be representative of construction conditions and are to be welded in the same manner as intended for the actual production welds. Where pre-fabrication primers are used in the shipyard, these are to be included in the test assemblies.

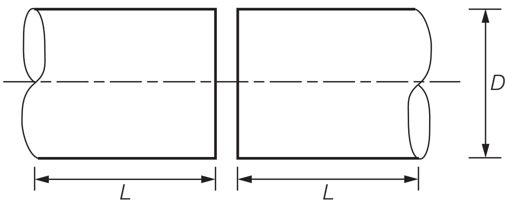
2.3.2 For plate tests, the direction of plate rolling relative to the weld direction is to be considered. Where the material used for the test requires longitudinal impact tests, the plate rolling direction is to be perpendicular to the weld direction and for material which requires impact testing in the transverse direction, the rolling direction is to be parallel to the weld direction. For weld tests intended for liquefied gas storage or cargo tanks and associated process pressure vessels, the direction of plate rolling is to be parallel to the weld direction in all cases.

2.3.3 Typical test assemblies are shown in Fig. 12.2.1(a) to (c). These are a minimum requirement to permit the removal of all the necessary mechanical test specimens. Where impact tests or other toughness tests are required, the total width is not to be less than 8 times the material thickness of the thicker material being joined.



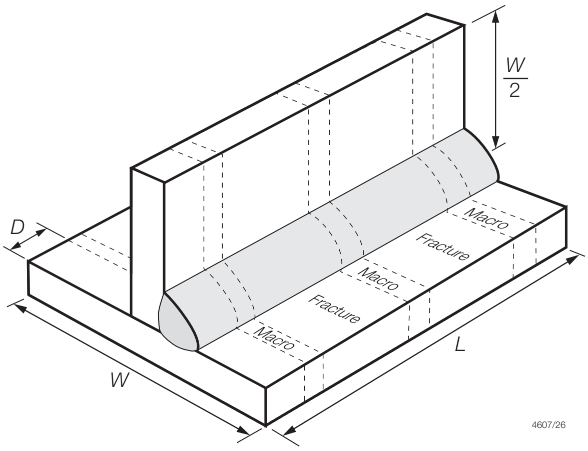
Welding Processes	*L* (min) mm	*W* (min) mm	*D* (min) mm
Manual/Semi-automatic	350	300	50
Automatic	1000	400	75

Fig. 12.2.1(a) Butt weld test assembly in plate



L = 150 mm minimum
D = Outside diameter

Fig. 12.2.1(b) Butt weld test assembly in pipe



Welding Processes	*L* (min) mm	*W* (min) mm	*D* (min) mm
Manual/Semi-automatic	350	300	50
Automatic	1000	300	75

Fig. 12.2.1(c) Fillet weld test assembly in plate

2.3.4 Welding procedure test assemblies are to be welded separately from production welds and are to be marked with the unique test identification number. The individual pieces of the test assembly may be held together to maintain their relative joint conditions by means of suitable tack welds, clamps or strongbacks.

2.3.5 Welding of the test assemblies and testing of test specimens is to be monitored by the Surveyor.

2.3.6 The test assembly is to be placed in one of the welding positions shown in Fig. 12.2.2(a) to (d), as specified in the test Welding Procedure Specification (pWPS) and the specified level of preheat applied prior to the start of welding.

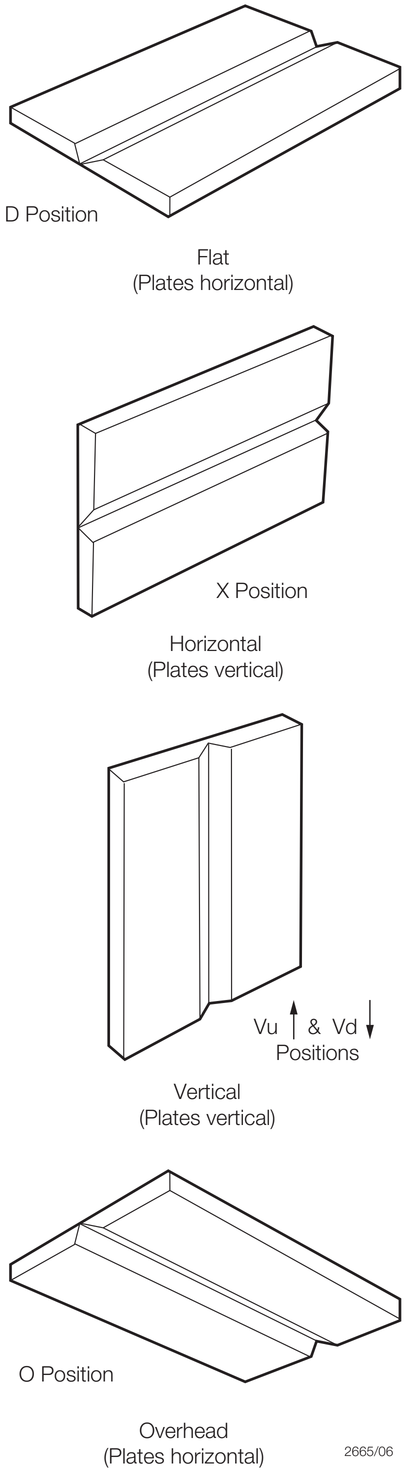
2.3.7 Designations for equivalent welding positions shown by different standards are shown in Table 12.2.1.

Table 12.2.1 Equivalent designations of welding positions

Weld position		Standard	
		ISO 6947	AWS
Plate butt welds			
Flat	D	PA	1G
Horizontal	X	PC	2G
Vertical, weld up	Vu	PF	3G
Vertical, weld down	Vd	PG	3G
Overhead	O	PE	4G
Pipe butt welds			
Pipe horizontal, rotated, weld horizontal	D	PA	1G
Pipe vertical, not rotated, weld horizontal	X	PC	2G
Pipe horizontal, not rotated, weld flat, vertical and overhead	D+Vu+O D+Vd+O	PF PG	5G
Pipe inclination fixed, not rotated	45°	H-L045 J-L045	6G
Plate fillet welds			
Flat	D	PA	1F
Horizontal	X	PB	2F
Vertical up	Vu	PF	3F
Vertical down	Vd	PG	3F
Overhead	O	PD	4F
Pipe fillet welds			
Flat, pipe rotated	D	PA	1FR
Horizontal, pipe fixed	X	PB	2F
Horizontal, pipe rotated	D	PB	2FR
Overhead, pipe fixed	O	PD	4F
Multiple, pipe fixed	D+Vu+O D+Vd+O	PF PG	5F

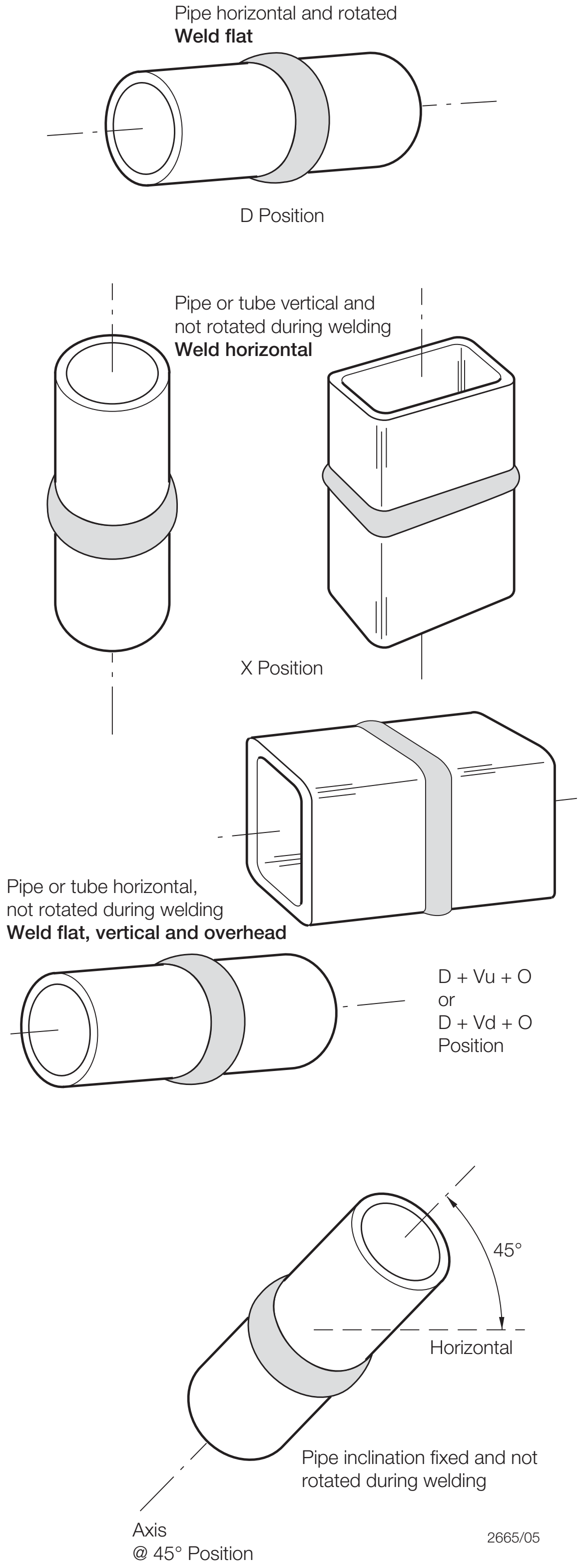
2.4 Welding of steel test assemblies

2.4.1 Welding of the test assembly is to be carried out in accordance with the agreed pWPS. Where, during the progress of the test, it is found necessary to change the conditions specified on the pWPS, this is to be brought to the attention of the Surveyor. If agreed, the test may be permitted to continue with the new conditions and these are to be recorded.



Position of test plates for plate assemblies

Fig. 12.2.2(a) Plate butt weld test positions



Position of pipes and welds for qualification weld test assemblies

Fig. 12.2.2(b) Pipe butt weld test positions

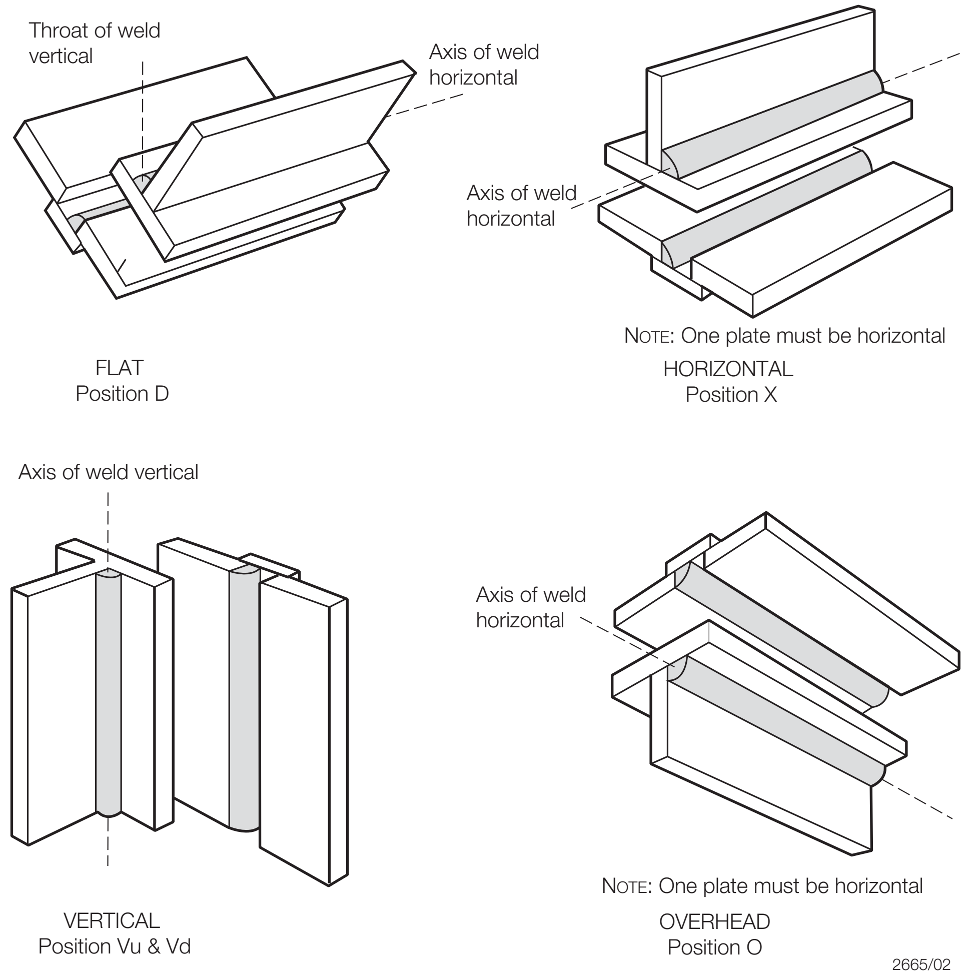


Fig. 12.2.2(c) Plate fillet weld test positions

2.4.2 Where the production work requires welding over tack welds, the test is to simulate this condition and the tack welds are to be included in the inspection length of the test weld and their position recorded.

2.4.3 For manual and semi-automatic welding processes, weld stops and re-starts are to be included in the inspection length of the test weld.

2.4.4 Fillet weld test assemblies are welded on one side only.

2.4.5 Where the construction welding is predominately fillet welding, in addition to the butt weld qualification test, a fillet weld qualification test is to be performed to confirm that acceptable weld quality is achieved.

2.5 Non-destructive examination (NDE)

2.5.1 On completion of welding, prior to sectioning for mechanical tests, the inspection length of the test assembly is to be subjected to both visual examination and surface crack detection.

2.5.2 Butt weld assemblies are also to be subjected to radiographic or ultrasonic examination over the whole inspection length of the weld.

2.5.3 For welds in steels with specified yield strength up to 400 N/mm^2, and with carbon equivalent less than or equal to 0,41 per cent, NDE may be performed as soon as the test assembly has cooled to ambient temperature. For other steels, NDE is to be delayed for a period of at least 48 hours after the test assembly has cooled to ambient temperature.

2.5.4 Where post-weld heat treatment is required, NDE is to be performed after the heat treatment is complete.

2.5.5 All NDEs are to be carried out in accordance with the requirements of Ch 1,5. Assessment of results is to be in accordance with ISO 5817 Level B except for excess convexity and excess throat thickness where Level C will apply. Linear porosity is not permitted.

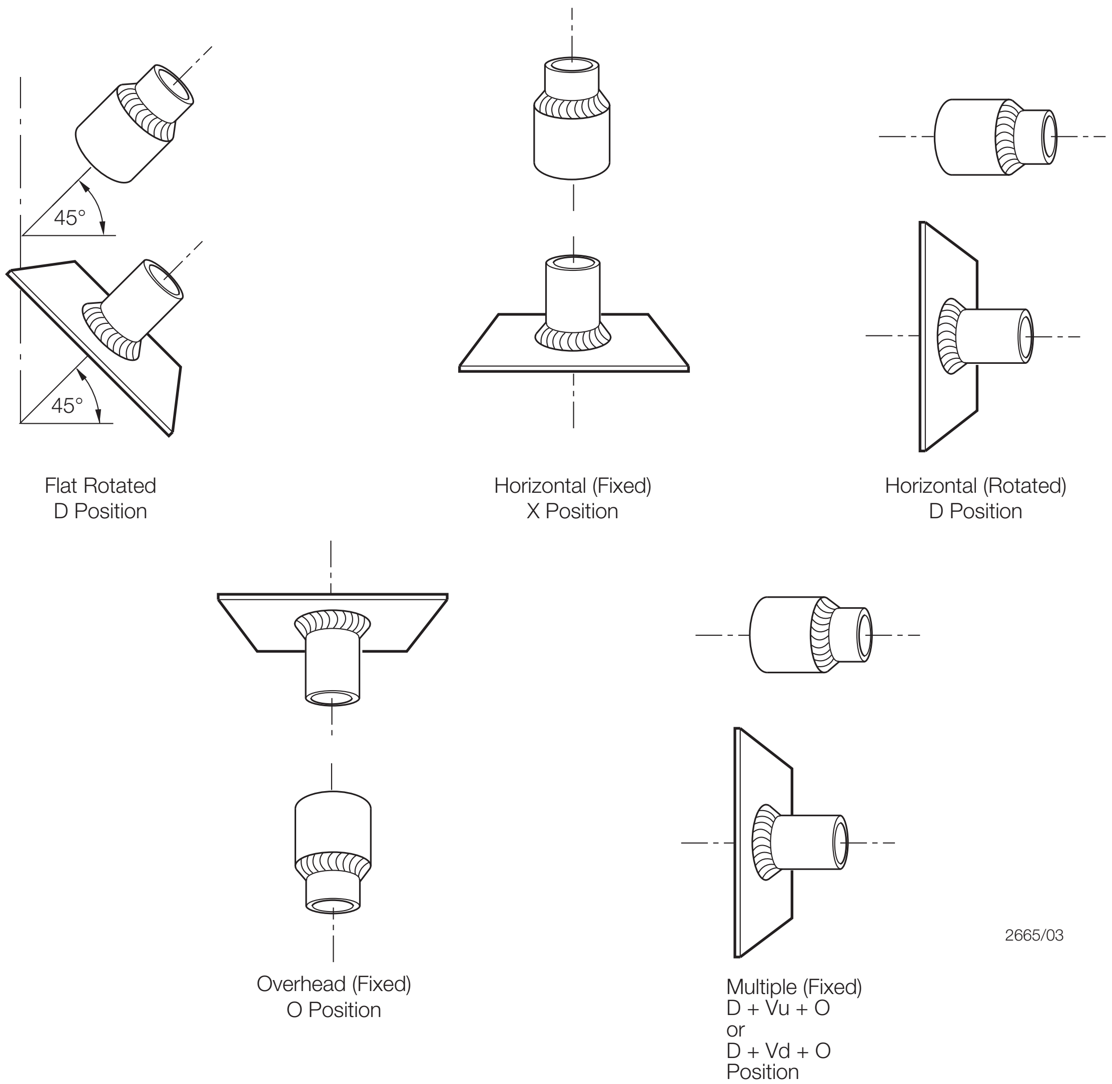


Fig. 12.2.2(d) Pipe fillet weld test positions

2.5.6 As an alternative to radiography, ultrasonic examination may be carried out and acceptance criteria that are considered to result in equivalent weld quality (in accordance with 2.5.5) are to be agreed, with the Surveyor, prior to the tests being carried out. Ultrasonic testing will be subject to the thickness limitation specified in Ch 13,2.12.5.

2.5.7 Where the test assembly does not satisfy the non-destructive examination acceptance criteria, the test is to be rejected. A duplicate test assembly may be welded using the original welding conditions. If this fails NDE, the welding procedure is to be considered as incapable of achieving the requirements without modification.

2.5.8 Subject to prior agreement with the Surveyor, where unacceptable imperfections are of a volumetric nature and are localised in one small area of the test assembly, the test may be permitted to continue and specimens for destructive testing may be removed, avoiding this area.

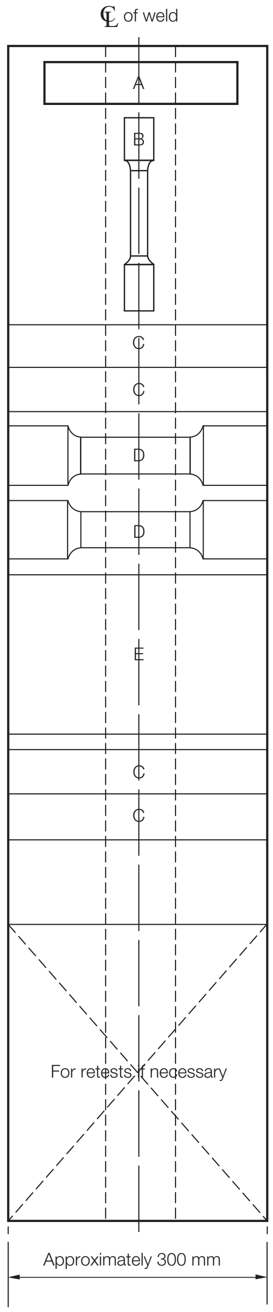
2.6 Destructive tests – General requirements

2.6.1 The weld test assembly may only be sectioned for destructive testing after any heat treatment and the required non-destructive examinations have been completed successfully.

2.6.2 The dimensions of the test specimens and testing conditions are to be in accordance with the requirements specified in Chapter 2.

2.6.3 The results of destructive tests are to be assessed in accordance with the acceptance criteria specified in 2.12, unless other, more stringent requirements are specified for the application.

2.6.4 Where a weld test is made between materials of different grades, the acceptance criteria that are to be applied are those applicable to the lower grade material.



Test requirements
A One macro including hardness survey
B All weld metal tensile test
C Four bend tests.
Two root bends and two face bends for thickness up to 12 mm.
For thickness above 12 mm four side bends
D Two transverse tensiles
E Five sets of Charpy V-notch impact tests, notched at the following positions:
1 set at weld centre
1 set at fusion line (FL)
1 set at FL + 2 mm
1 set at FL + 5 mm (if required by Figs. 12.2.6 and 12.2.7)
1 set at FL + 10 mm (if required)

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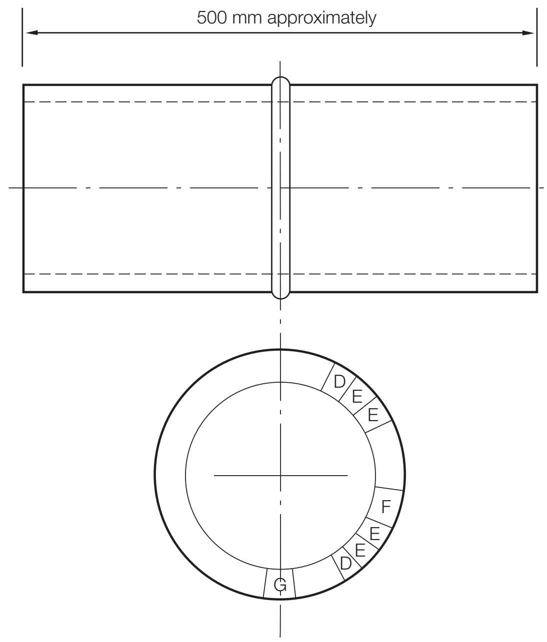
Fig. 12.2.3
Butt welds in plate and pipe over 750 mm diameter



The diameter of the test piece is to be a minimum of *D*/2
where
D is the maximum diameter of the pipe to be welded in construction

Test requirements
A Visual examination
B Surface crack detection
C 100% radiographic examination
D Two transverse tensile tests
E Four bend tests.
Four side bends for thickness greater than 12 mm.
In other cases, two face and two root bends
F Four sets Charpy V-notch impact tests
1 set notched at centre of weld
1 set notched at fusion line (FL)
1 set notched at FL + 2 mm
1 set notched at FL + 5 mm (if required by Figs. 12.2.6 and 12.2.7)
G One macro specimen including hardness survey

Fig. 12.2.4
Butt welds in pipe less than 750 mm diameter

2.7 Destructive tests for steel butt welds

2.7.1 The test assembly is to be sectioned for mechanical testing in accordance with Figs. 12.2.3 or 12.2.4.

2.7.2 The longitudinal all weld metal tensile test specimen is to be of circular cross-section as detailed in Ch 11,2.1.1. Where more than one welding process or type of consumable has been used to make the weld, test specimens are to be removed from each respective area of the weld. This does not apply to the process or consumables used to make the root or first weld run. During the test, the yield or proof stress, ultimate tensile strength, and elongation to failure are to be recorded.

2.7.3 Where approved welding consumables have been used, the longitudinal all weld metal tensile test may be omitted. For Type C independent tanks intended for liquefied gases, the all weld tensile test is mandatory for all welding procedure tests.

2.7.4 The transverse tensile test specimen is to be of full thickness with the dimensions shown in Ch 11,2.1.1. The tensile strength and fracture locations are to be reported.

2.7.5 Where the maximum load required to fracture the transverse tensile specimen is likely to exceed the capacity of the tensile testing equipment, several tensile specimens may be removed through the thickness and tested. Specimens are to be prepared such that they overlap in the thickness direction so that the full plate thickness is tested.

2.7.6 Transverse bend specimens of rectangular section are to be prepared with the weld centred in the middle of the specimen as shown in Fig. 12.2.5. For material of thickness 12 mm or greater, the face and root bends may be substituted by side bend tests. Where there is a significant difference between the strength of the weld and base material, longitudinal bend specimens may be used.The weld reinforcement may be removed by grinding or machining prior to testing and the edges rounded to a radius not exceeding 10 per cent of the specimen thickness. Each specimen is to be bent through an angle of at least 180°. The bend test ratio is to be the lesser of the following:

(a) $D_f = (D/t) + 1$

or

(b) $D_f = 100/E_m$ (rounded up to the next whole number)

where

D_f = is the bend test ratio

(D/t) = is the value from Tables 11.3.3, 11.4.3 or 11.8.2 in Chapter 11, as appropriate

E_m = is the minimum specified percentage elongation for the test material (based on a proportional gauge length of $5,65\sqrt{S_o}$)

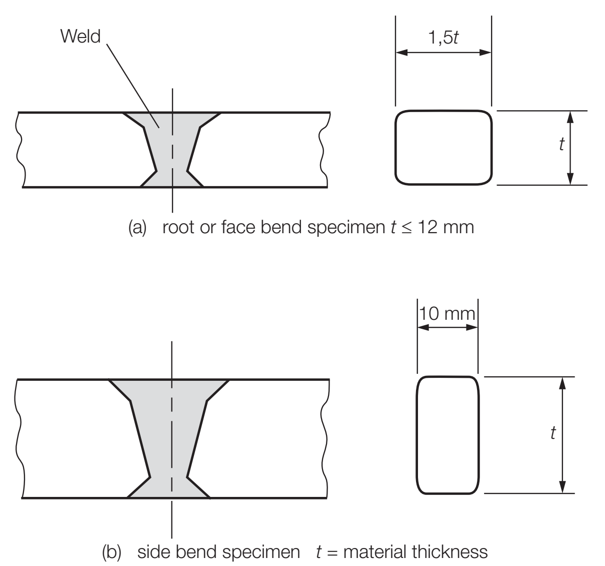


Fig. 12.2.5 Transverse bend test specimens

2.7.7 Where the weld test is made between different material types, the requirements of 2.7.8 are to be applied to the material with the lower toughness specification.

2.7.8 For hull structural steels, impact test specimens are to be prepared from the locations shown in Figs. 12.2.6 or 12.2.7, with the notch perpendicular to the plate surface and have the dimensions and proportions in accordance with Ch 2,3. Where more than one welding process or type of consumable has been used to make the weld, test specimens are also to be removed from these respective parts of the weld. Note that this does not apply to the welding process or consumables used solely to make the root or first weld run. Where the weld thickness exceeds 50 mm, an additional set of impact tests is required from the root area of the weld irrespective or whether different welding process or welding consumables are used as shown in Figs. 12.2.6 and 12.2.7.

2.7.9 For offshore structures and pressure vessels, impact test specimens are not required to be notched at the FL + 10 mm location. Where more than one welding process or type of consumable has been used to make the weld, test specimens are to be removed from the respective areas of the weld. This does not apply to the process or consumables used solely to make the root or first weld run.

2.7.10 For pressure vessels and tanks employed in transportation of liquefied gases, Charpy impact test locations from the weld and heat affected zone are to be in accordance with Fig. 12.2.8.

2.7.11 At least one macro examination specimen is to be removed from the test plate, near the end where welding started. The specimen is to include the complete cross-section of the weld and the heat affected zone and be prepared and etched to clearly reveal the weld runs and the heat affected zone. Examination is to be performed under a magnification of between x5 and x10.

2.7.12 A chemical analysis of the weld metal is to be performed on the macro specimen where approved welding consumables have not been used. The results are to comply with the limits given in the welding consumable specification.

2.7.13 A Vickers hardness survey is to be performed on the macro specimen taken from the weld start end of the test assembly in accordance with that shown in Fig. 12.2.9, using a test load not in excess of 10 kg. For each row of indents, there are to be a minimum of 3 individual indentations in the weld metal, the heat affected zones (both sides) and the base metal (both sides). The recommended distance between indents is 1,0 mm, but the distance between indents should not be less than the minimum specified in ISO 6507/1.

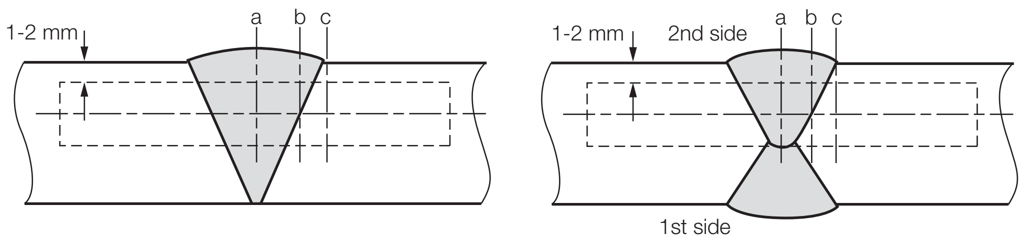
2.8 Destructive tests for steel fillet welds

2.8.1 Fillet weld test assemblies are to be sectioned for destructive testing in accordance with Fig. 12.2.1(c) and as follows:

(a) two fracture tests;
(b) three macro-sections;
(c) one hardness survey.

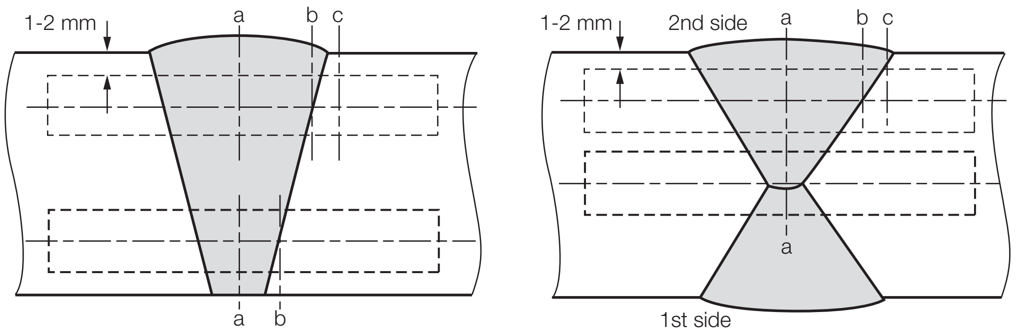
2.8.2 Two fracture test specimens are to be removed from the test weld and are to be subjected to testing by bending the upright plate onto the through plate to produce fracture, as shown in Fig. 12.2.1(c).

(a) $t \leq$ 50 mm, *see* Note



NOTE
For one side single run welding over 20 mm notch location ‘a’ is to be added on root side

(a) t > 50 mm



Notch locations:
a : centre of weld ‘WM’
b : on fusion line ‘FL’
c : in HAZ, 2mm from fusion line

Fig. 12.2.6 Locations of V-notch for butt weld of normal heat input (heat input ≤ 50 kJ/cm)

2.8.3 At least three macro examination specimens are to be removed from the test plate. The specimens are to include the complete cross-section of the weld and the heat affected zone and is to be prepared to clearly reveal the weld runs and the heat affected zone. One of the specimens is to include a weld stop/start position. Examination is to be performed under a magnification of between x5 and x10.

2.8.4 A Vickers hardness survey is to be performed on the macro specimen taken from the weld start end of the test assembly in accordance with that shown in Fig. 12.2.10, using a test load not exceeding 10 kg.

2.9 Destructive tests for T, K, Y steel nozzle welds

2.9.1 Full penetration ‘T’, ‘K’ and ‘Y’ joints for structural applications and nozzle welds for pressure vessels are to be sectioned for testing in accordance with Fig. 12.2.11 and tested as detailed below:

(a) three macro specimens;
(b) impact tests from the weld, fusion line and fusion line + 2 (where the material thickness permits);
(c) one hardness survey.

In addition, butt weld tests are to be performed in accordance with 2.7, using the same welding conditions, in order to verify acceptable weld and heat affected zone properties.

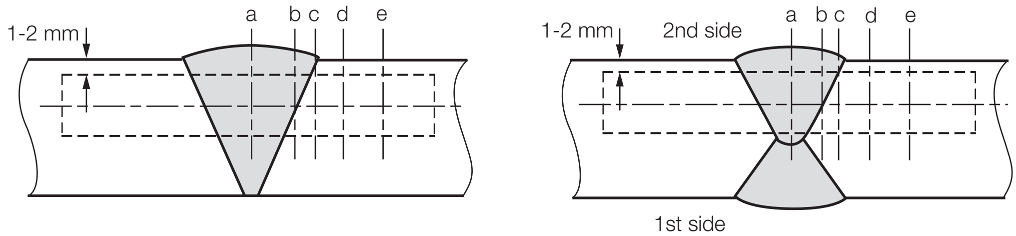
2.9.2 The impact tests are to be removed from the vertical (up) position ‘B’ in Fig. 12.2.11 and tested in accordance with 2.7.8.

2.9.3 A Vickers hardness survey is to be performed on the macro-section removed from position ‘A’ or ‘C’ in accordance with that shown in Fig. 12.2.12 using a test load not exceeding 10 kg.

2.10 Destructive tests for steel pipe branch welds

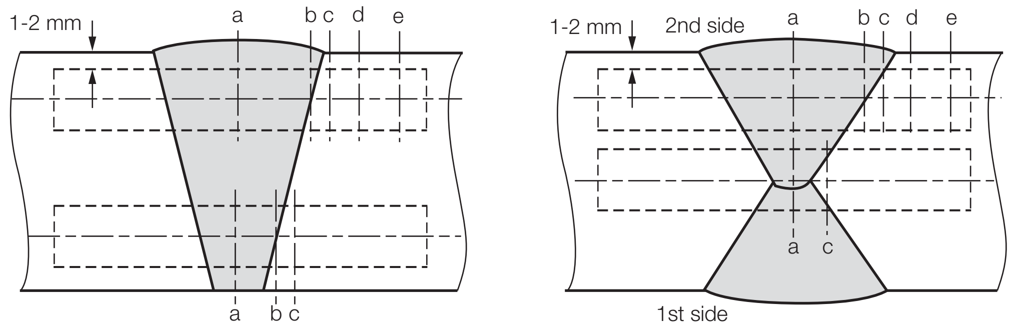
2.10.1 Pipe branch welds may be by either full penetration, partial penetration or fillet welded, depending on the application and the approved plans. Where these types of welded joints are used, tests are to be performed which simulate the construction conditions.

(a) *t* ≤ 50 mm, *see* Note



NOTE
For one side welding with thickness over 20 mm notch location 'a', 'b' and 'c' are to be added on root side

(a) *t* > 50 mm



Notch locations:
a : centre of weld 'WM'
b : on fusion line 'FL'
c : in HAZ, 2 mm from fusion line
d : in HAZ, 5 mm from fusion line
e : in HAZ, 10 mm from fusion line in case of heat input > 200 kJ/cm

Fig. 12.2.7 Locations of V-notch for butt weld of high heat input (heat input > 50 kJ/cm)

2.10.2 The test weld assembly is to simulate the smallest angle between the branch and main pipe and is to be subjected to macro-examination and hardness testing, as follows:

(a) For a branch weld that is full penetration, testing is to be performed in accordance with the requirements for 'T', 'K' and 'Y' joints in 2.9.
(b) For a branch weld that is either a partial penetration or fillet weld, testing is to be in accordance with the requirements for fillet welds in 2.8.

2.11 Destructive tests for weld cladding of steel

2.11.1 Where weld cladding or overlay is allowed by Chapter 13, and is considered as providing strength to the component to which it is welded, the type and location of test specimens are to be in accordance with Fig. 12.2.13, except that micro-sections are not required. Impact tests may be omitted where the base material does not have specified impact properties. The longitudinal tensile and bend tests are to be tested in a similar manner to transverse specimens specified in 2.7.2 and 2.7.6, respectively.

2.11.2 Where the weld cladding is not considered as contributing to the strength of the component, but is required for corrosion or wear resistance, the type and location of test specimens are to be in accordance with Fig. 12.2.13, except that tensile and impact tests are not required.

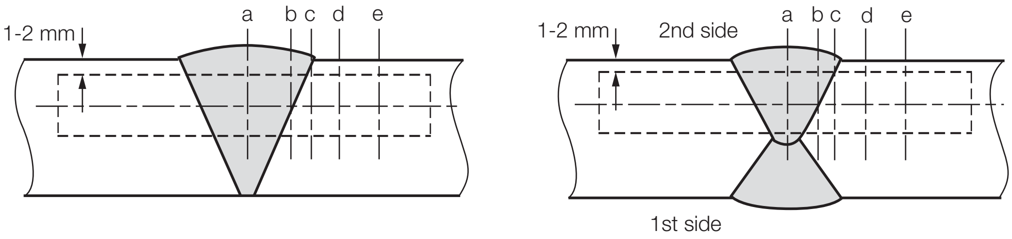
2.11.3 Where the weld cladding is applied for corrosion resistance, in addition to the above, weld metal analysis is to be performed on one of the micro-sections, on the final weld surface but 2 mm deep. The analysis is to be within the limits specified for the corrosion resistance required.

2.12 Mechanical test acceptance criteria for steels

2.12.1 **Longitudinal all weld metal tensile test**:

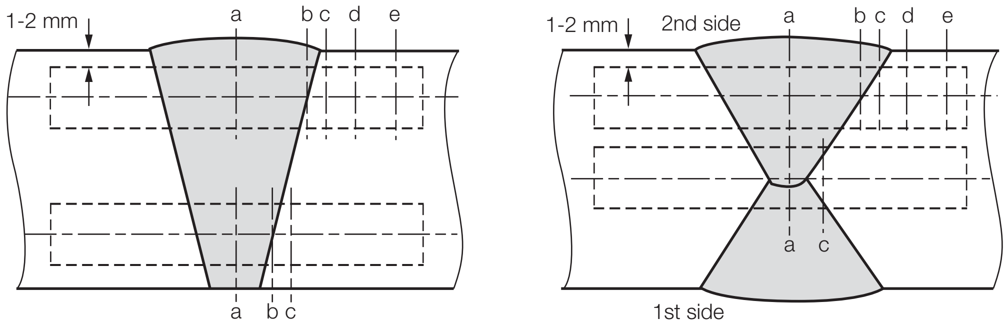
(a) In general, the longitudinal all weld tensile test is to meet the minimum properties specified in Tables 11.3.2 or 11.4.2 in Chapter 11, as appropriate to the grade of steel and welding process used in the test.
(b) Where the application is such that no consumable approvals are specified in Chapter 11, the longitudinal all weld tensile test tensile is to meet the minimum properties specified for the base materials used in the test.

(a) $t \le 50$ mm, *see* Note



NOTE
For one side welding with thickness over 20 mm notch locations 'a', 'b' and 'c' are to be added on root side

(a) $t > 50$ mm



Notch locations:
a : centre of weld 'WM'
b : on fusion line 'FL'
c : in HAZ 1 mm from fusion line
d : in HAZ 3 mm from fusion line
e : in HAZ 5 mm from fusion line
f : in base metal remote from weld (Type C independent tanks only)

Fig. 12.2.8 Locations of V-notch tests for butt welds intended for liquefied gas containment systems

(c) For pressure vessels manufactured from carbon or carbon/manganese steels, the tensile strength from the longitudinal all weld tensile test is not to be less than the minimum specified for the plate material and is not to be more than 145 N/mm^2 above this value, *see* Ch 13,4.8.3.

(d) For tanks intended for liquefied gases, the weld metal strength may be lower than the minimum specified for the base metal provided that the application has design approval. In such cases the strength is not to be less than that specified in the approved design.

2.12.2 **Transverse tensile test**: The tensile strength measured from the transverse tensile test is not to be less than the minimum specified for the base material used in the test. For tanks intended for liquefied gases, a lower ultimate tensile may be accepted subject to design approval as in 2.12.1(d).

2.12.3 **Bend tests**:

(a) In general, bend tests are to exhibit no defects exceeding 3,0 mm measured in any direction across the tension face of the specimen after being bent over the required diameter of former to the appropriate angle.

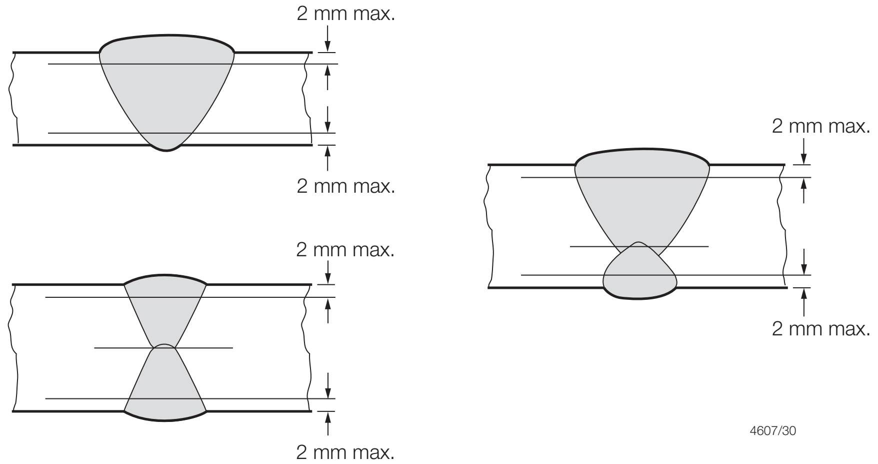
(b) Bend tests for pressure vessel applications are to exhibit no defects exceeding 3,0 mm measured along the specimen or 1,5 mm measured transverse to the specimen axis, after bending.

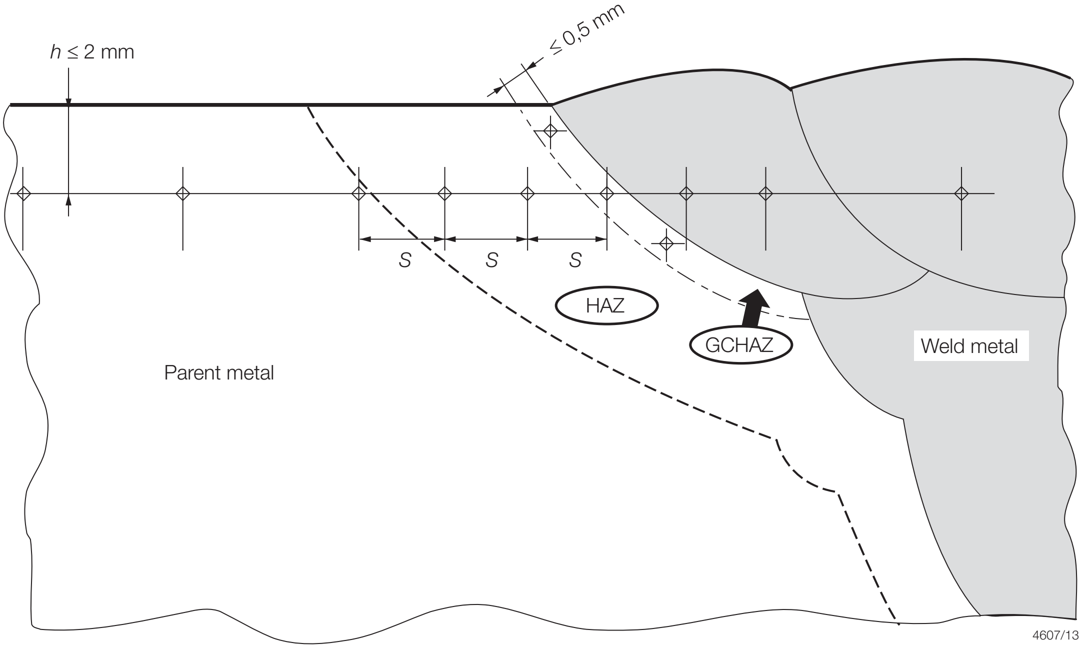
(c) In all cases, premature failure of the bend tests at the edges of the specimen is to not be cause for rejection unless these are associated with a weld defect.

2.12.4 **Impact toughness tests**:

(a) Impact test specimens for hull construction are to be tested at the temperature, and are to achieve the minimum impact energy, as specified in Tables 12.2.2 and 12.2.3.

(b) Impact test specimens for applications other than hull construction are to be tested at the same temperature and achieve the same minimum energy values, as specified for the base materials used in the test.





HAZ	Heat affected zone
GCHAZ	Grain coarsened heat affected zone
S	Indentation spacing

Fig. 12.2.9 Hardness testing locations for butt welds

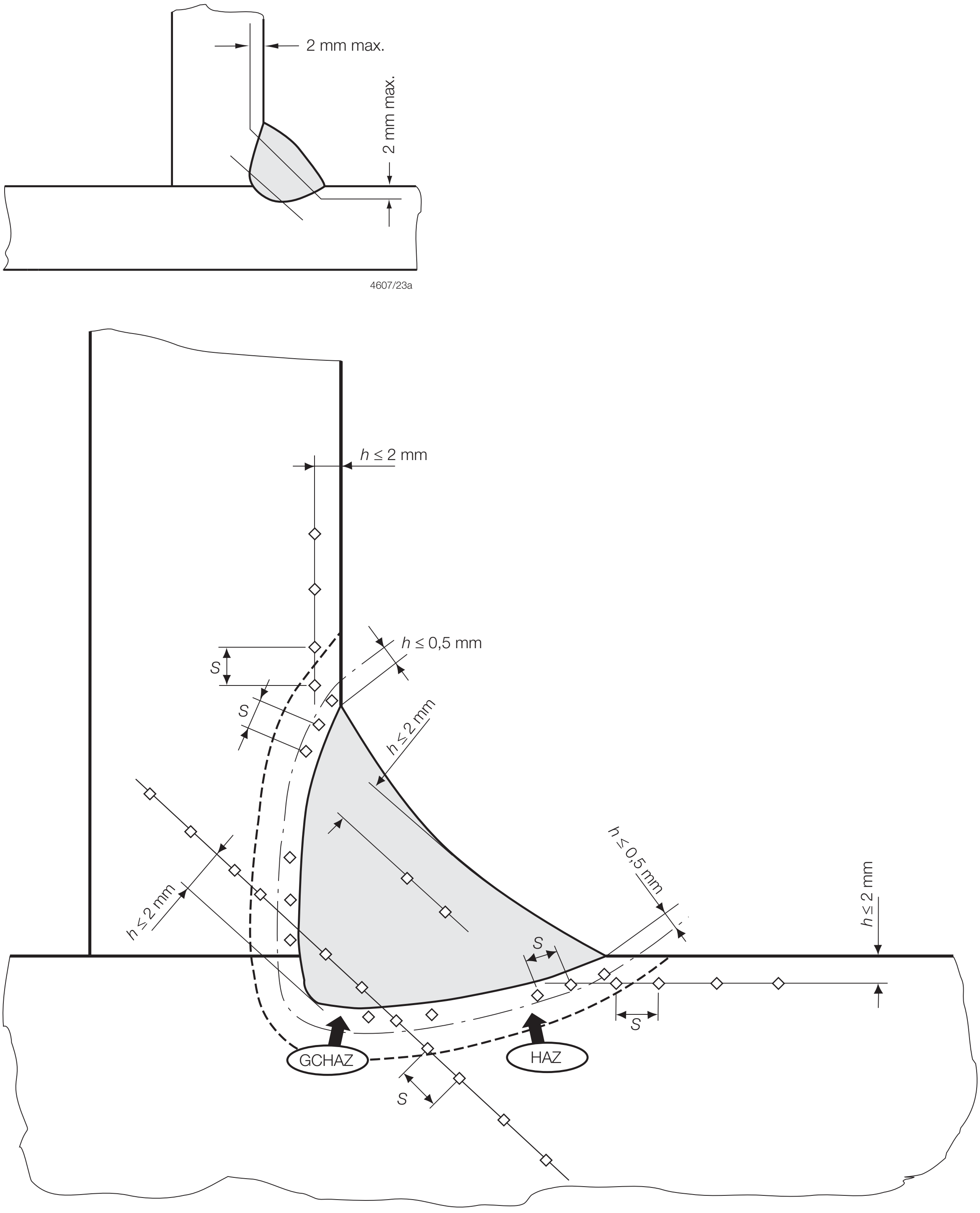
(c) Impact test acceptance criteria are to be in accordance with the above unless the Rules applicable to the particular construction specify more stringent requirements.

(d) For quench and tempered steels, the required test temperature and absorbed energy are to be in accordance with that specified for the parent materials.

2.12.5 **Macro-examination**: The macro-section is to reveal an even weld profile blending smoothly with the base material. The weld dimensions are to be in accordance with the requirements of the pWPS and any defects present are to be assessed against the non-destructive examination acceptance criteria given in 2.5.5.

2.12.6 **Hardness surveys**: The maximum hardness value reported, is not to exceed 350 Hv for steels with a specified minimum yield strength up to ≤420 N/mm^2, nor exceed 420 Hv for steels with a specified minimum yield strength in the range 420 N/mm^2 to 690 N/mm^2.

2.12.7 **Weld fracture or break tests (for pressure vessel test welds)**: The faces of the broken fillet weld fracture or weld break test are to be examined for defects and assessed in accordance with the non-destructive acceptance criteria given in ISO 5817 Level B, except for excess convexity and excess throat thickness where Level C will apply.



HAZ	Heat affected zone
GCHAZ	Grain coarsened heat affected zone
S	Indentation spacing

Fig. 12.2.10 Hardness test locations for fillet welds

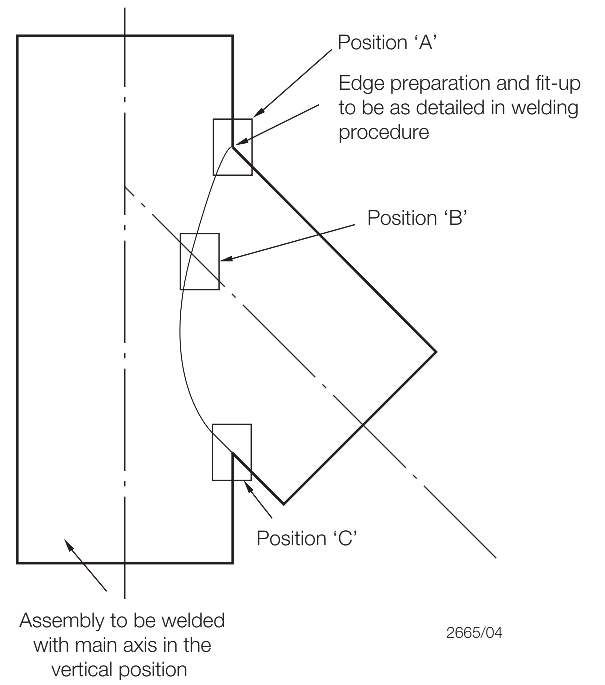


Fig. 12.2.11
Location of macro-examination test specimens for T, K and Y joints

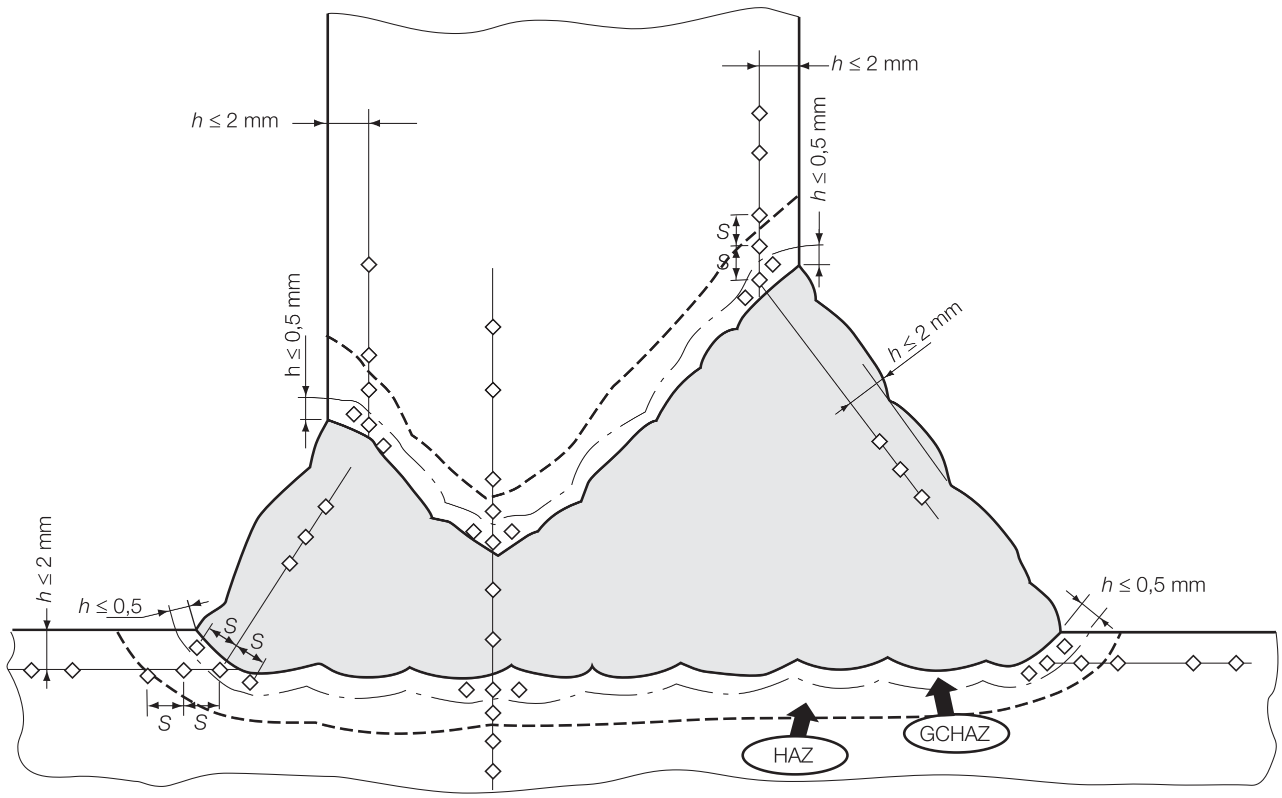
2.13 Failure to meet requirements (Retests)

2.13.1 Where a tensile, bend or hardness specimen fails to meet requirements, further test specimens may be removed and tested in accordance with the requirements of Ch 2,1.4.1.

2.13.2 Where an impact specimen fails to meet requirements, a further set of three specimens may be removed and tested in accordance with the requirements of Ch 2,1.4.4.

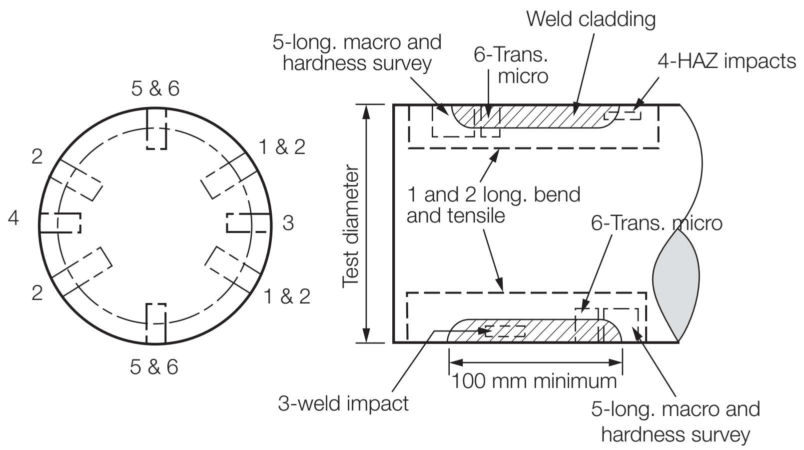
2.13.3 Where a macro specimen reveals a defect that is planar in nature, the welding procedure test is to be considered as not satisfying the requirements and a new test assembly is required.

2.13.4 Where a macro specimen does not meet requirements as a result of a volumetric imperfection exceeding the permitted size, two additional specimens may be removed from the same test weld and examined. If either of these macro-sections also fails to satisfy the requirements, the welding procedure is to be considered as not having met the requirements.



HAZ Heat affected zone
GCHAZ Grain coarsened heat affected zone
S Indentation spacing

Fig. 12.2.12 Hardness test locations for T, K and Y joints



Test specimens
1 Longitudinal tensile test to include the weld metal, heat affected zone (HAZ) and base metal.
2 Longitudinal side bend test to include the weld metal, heat affected zone (HAZ) and base metal.
3 Weld metal Charpy V notch impact test.
4 HAZ Charpy impact test from Fusion Line and Fusion Line + 2 mm.
5 Longitudinal macro-section and hardness survey.
6 Transverse micro-section.

NOTE
In the case of shafts and pipes of circular section, the longitudinal direction is parallel to the centreline of the shaft or pipe axis.

Fig. 12.2.13 Type and location of test specimens for weld cladding

Table 12.2.2 Impact test requirements for butt joints ($t \leq 50$ mm) *see* Notes 1 and 2

Grade of steel	Test temperature (°C) *see* Note 4	Value of minimum energy absorbed (J), *see* Note 4		
		Manual or semi-automatic welded joints		Automatically welded joints
		Downhand, Horizontal, Overhead	Vertical upward, Vertical downward	
A, *see* Note 3 B, *see* Note 3, D E A32, A36 D32, D36 E32, E36 F32, F36	20 0 –20 20 0 –20 –40	47	34	34
A40 D40 E40 F40	20 0 –20 –40		39	39

NOTES
1. Steel with yield strength greater than 390 N/mm^2 is not permitted in thickness less than 50 mm, *see* Table 3.3.1 in Chapter 3.
2. These requirements are to apply to test piece of which butt weld is perpendicular to the rolling direction of the plates.
3. For grade A and B steels average absorbed energy on fusion line and in heat affected zone is to be a minimum of 27 J.
4. For Naval ships both the test temperature and value of minimum energy absorbed are to be those specified for the parent material.

2.13.5 If there is a single hardness value above the maximum values specified, additional hardness tests are to be carried out, either on the reverse of the specimen, or after sufficient grinding of the tested surface. None of the additional hardness values is to exceed the maximum hardness values specified, otherwise the welding procedure is to be considered as not having met the requirements.

2.13.6 Where there is insufficient material available in the welded test assembly to provide re-test specimens, subject to prior agreement with the Surveyor, a second assembly may be welded using the same conditions as the original test weld.

Table 12.2.3 Impact test requirements for butt joints (*t* > 50 mm), *see* Note 1

Grade of steel	Test temperature (ºC) see Note 2	Value of absorbed energy (J, min), *see* Note 2		
		Manual or semi-automatic welded joints		Automatically welded joints
		Downhand, Horizontal, Overhead	Vertical upward, Vertical downward	
A	20	34	34	34
B	0	34	34	34
D	0	47	38	38
E	–20	47	38	38
AH32, AH36	20	47	41	41
DH32, DH36	0	47	41	41
EH32, EH36	–20	47	41	41
FH32, FH36	–40	47	41	41
AH40	20	50	46	46
DH40	0	50	46	46
EH40	–20	50	46	46
FH40	–40	50	46	46
AH47	20	53	53	53
DH47	0	53	53	53
EH47	–20	53	53	53
FH47	–40	53	53	53

NOTES
1. These requirements are to apply to test piece of which butt weld is perpendicular to the rolling direction of the plates.
2. For the Naval ships both the test temperature and value of minimum absorbed energy are to be those specified for the parent material.

2.14 Test records

2.14.1 The procedure qualification record (PQR) is to be prepared by the manufacturer and is to include details of the welding conditions used in the test specified in 2.2 and the results of all the non-destructive examinations and destructive tests, including re-tests.

2.14.2 Provided that the PQR lists all the relevant variables and there are no inconsistent features and the results satisfy the requirements, the PQR may be endorsed by the Surveyor as satisfying the requirement of the Rules, *see also* 1.1.4.

2.15 Range of approval

2.15.1 A welding procedure qualification test that has successfully met the requirements may be used for a wider range of applications than those used during the test.

2.15.2 Changes outside of the ranges specified are to require a new welding procedure test.

2.15.3 Other ranges of approval from those specified in this Section may be agreed with the Surveyor, provided that they are in accordance with recognised National or International Standards.

2.15.4 **Manufacturer**. A welding procedure qualified by a manufacturer is valid for welding in workshops under the same technical and quality management.

2.15.5 **Welding process and technique**. The welding process and welding techniques approved are to be those employed during the welding procedure qualification test. Where multiple welding processes are used, these are to be employed in the same order as that used in the welding procedure qualification test. However, it may be acceptable to delete or add a welding process where it has been used solely to make the first weld run in the root of the joint, provided back gouging or grinding of the root weld is specified on the WPS. For multi-process procedures, the welding procedure approval may be carried out with separate welding procedure tests for each welding process.

2.15.6 **Welding positions**. Approval for a test made in any position is restricted to that position. To qualify a range of positions, test assemblies are to be welded for the highest heat input position, and the lowest heat input position, and all applicable tests are to be made on those assemblies. The above excludes welding in the vertical position with travel in the downward direction which will always require separate qualification testing and only be acceptable for that position.

2.15.7 **Joint types**. A qualification test performed on a butt weld may be considered acceptable for fillet and partial penetration welds, provided the same welding conditions are used. The range of approval depending on the type of joint for butt welds is given in Table 12.2.4.

Table 12.2.4 Range of approval for different types of butt joints

Type of welded joint for test assembly				Range of approval
Butt welding	One side	With backing Without backing	A B	A,C A,B,C,D
	Both sides	With gouging Without gouging	C D	C C,D

2.15.8 **Range of material types**:

(a) A qualification test performed on one strength level of steel may be used to weld all similar materials with the same or lower specified minimum yield stress with the exception of the two-run (T) or high welding heat input (A) techniques where acceptance is limited to the strength level used in the test. Similarly, a qualification test performed on a steel with one toughness level may be considered acceptable for welding all similar materials with the same or three toughness grades lower specified minimum toughness level.

(b) A qualification test performed on H47 strength grade steels may be used to weld the steel of the same strength level or grade H40 and all lower toughness grades to that tested.

(c) For high strength quenched and tempered steels, for each strength level, welding procedures are considered applicable to the same and lower toughness grades as that tested. For each toughness grade, welding procedures are considered applicable to the same and one lower strength level as that tested. The approval of quenched and tempered steels does not qualify thermo-mechanically rolled steels (TMCP steels) and vice versa.

(d) For weldable C and C-Mn steel forgings, welding procedures are applicable to the same and lower strength level as that tested. The approval of quenched and tempered steel forgings does not qualify other delivery conditions and vice versa.

(e) For weldable C and C-Mn steel castings, welding procedures are applicable to the same and lower strength level as that tested. The approval of quenched and tempered steel castings does not qualify other delivery conditions and vice versa.

Dissimilar materials. Where a qualification test has been performed using dissimilar materials, acceptance is to be limited to the materials used in the test.

2.15.9 **Thickness and diameter range**:

(a) For straight butt welds, the material thickness range to be approved is to be based on the thickness of the test piece and the type of weld as shown in Table 12.2.5.

(b) For butt welds between plates of unequal thickness, the lesser thickness is the ruling dimension.

(c) For fillet welds and 'T' butt welds, Table 12.2.5 is to be applicable to both the abutting and through member thicknesses. In addition to the requirements of Table 12.2.5, the range of approval of throat thickness '*a*' for fillet welds is to be as follows:

- single run: 0,75*a* to 1,5*a*
- multi-run: as for butt welds with multi-run (i.e. $a = t$)

Table 12.2.5 Welding procedure thickness approval range – Butt welds

Test thickness, *see* Note 1 (t in mm)	Range approved	
	All multi-run butt welds and all fillet welds *see* Notes 3 and 4	All single-run or two-run two-run (T technique) butt welds
$t \le 3$	t to $2t$	0,7t to 1,1t
$3 < t \le 12$	3 to $2t$	0,7t to 1,1t
$12 < t \le 100$	0,5t to $2t$, *see* Note 2	0,7t to 1,1t *see* Note 5
$t > 100$	0,5t to 1,5t	0,7t to 1,1t *see* Note 5

NOTES
1. Where the test plates have dissimilar thickness, the thickness, t, is to be based on the minimum thickness for butt welds and the maximum thickness for fillet welds.
2. Subject to a maximum limit of 150 mm.
3. For multi process procedures, the recorded thickness contribution of each process is to be used as a basis for the range of approval of the individual welding process.
4. For vertical down welding, the test piece thickness, t, is the upper limit of the range of application.
5. For processes with heat input over 5,0 kJ/mm, the upper limit of the range of approval is to be 1,0 t.

(d) Notwithstanding any of the above, the approval of maximum thickness of base metal for any technique is to be restricted to the thickness of the test assembly if three of the hardness values in the heat affected zone are found to be within 25 Hv of the maximum permitted.

(e) The material diameter range to be approved is to be based on the diameter of the test piece and type of weld as shown in Table 12.2.6.

Table 12.2.6 Diameter range approved

Diameter used for test, *see* Note 1	Range of diameters approved
$D \le 25$ mm	0,5D to 2D
$D > 25$ mm	> 0,5D, *see* Note 2

NOTES
1. D is the outside diameter of the pipe or the smallest side dimension of rectangular hollow section.
2. Lower diameter range limited to 25 mm minimum.

2.15.10 **Welding consumables**:

(a) For manual and semi-automatic welding used for the fill and capping weld runs, it may be acceptable to change the brand or trade name of the welding electrode or wire from that used in the test, provided the proposed alternative has the same or higher approval grading and the same flux type (e.g. basic low hydrogen, rutile, etc.) as used in that test.

(b) For the consumable used to make the root weld of full penetration butt welds made from one side only, no change in the type or trade name of the consumable or backing material is permitted. Alternative backing materials may be used provided they are equivalent to those used for approval. Where the approved backing material is a low hydrogen grade and the steel being welded requires a low hydrogen backing material, testing of the alternative backing material is to confirm compliance with the requirements of Ch 11,7

(c) For processes with heat input over 5 kJ/mm, no change in the type or trade name of the consumable is permitted.

2.15.11 **Shielding gas**. For gas shielded welding processes, a change in shielding gas composition from that used in the test will require a new qualification test.

2.15.12 **Heat Input**. The upper limit of heat input approved is 25 per cent greater than that used in the test, or 5,5 kJ/mm, whichever is the smaller. With heat input over 5,0 KJ/mm, the upper limit is 10 per cent above that used in the test. In all cases, the lower limit of heat input approved is 25 per cent lower than that used in the test.

2.15.13 **Current type**. The current type used during the qualification test is to be the only type approved. Additionally, changes from or to pulsed current require new qualification tests.

2.15.14 **Preheat temperature**. The temperature used during the test is to be the minimum approved. Higher temperatures may be specified for production welds up to the maximum interpass temperature. Where hardness tests have been performed that exhibit results near the maximum permitted, an increase in preheat temperature is required when welding material of greater thickness than that used in the test.

2.15.15 **Interpass temperature**. The maximum interpass temperature recorded during qualification testing is to be the maximum approved. Lower temperatures may be specified for production welding, but no lower than the minimum preheat temperature.

2.15.16 **Post-weld heat treatment**. A qualification test performed with no post weld heat treatment is only acceptable for production welding where no heat treatment is applied. Where the qualification test has included a post weld heat treatment, this is to be applied to all welds made with the welding procedure. The average specified soak temperature may vary by up to 25°C from that tested.

2.15.17 **Shop primers.** Welding procedure qualification with shop primers qualifies welds without primer, but not vice versa.

2.16 Welding procedure specification (WPS)

2.16.1 A welding procedure specification (WPS) is to be prepared by the manufacturer detailing the welding conditions and techniques to be employed for production welding. The WPS is to be based on the conditions and variables used during the qualification test, and is to include all the ranges of the essential variables specified in 2.2.1 and 2.15.

2.16.2 The WPS should reference the procedure qualification record upon which it is based and is to be approved by the Surveyor prior to commencing production welding.

■ *Section 3* Specific requirements for stainless steels

3.1 Scope

3.1.1 The requirements of this Section relate to the group of steel materials classed as stainless steels and include austenitic and duplex grades and martensitic grades.

3.1.2 In all cases, welding procedure tests are to be performed generally in accordance with Section 2 with the specific requirements specified below.

3.2 Austenitic stainless steels

3.2.1 The requirements of this Section relate to the group of stainless steel materials that are austenitic at ambient and sub-zero temperatures, (e.g., 304L, 316L types), *see* Table 3.7.1 in Chapter 3.

3.2.2 Impact tests are to be performed from specimens removed from the weld metal. Tests in the heat affected zone are not required.

3.2.3 Hardness tests are generally not required.

3.2.4 For cryogenic or corrosion resistant applications, the ferrite content in the weld cap region is to be measured and is to be in the range 2 to 10 per cent, with the exception of grades S 31245 and N 08904 where the content is to be nominally zero.

3.2.5 A qualification test performed on an austenitic grade may be considered acceptable for welding other austenitic steels with the same or lower level of alloying elements and the same or lower tensile strength.

3.2.6 A qualification test performed for cryogenic applications may be considered acceptable for chemical applications, but not vice versa.

3.3 Duplex stainless steels

3.3.1 The requirements of this Section relate to the group of stainless steel materials that have a ferritic-austenitic structure and are usually referred to as duplex or super duplex stainless steels (e.g.,S 31803, S 32760).

3.3.2 Impact test specimens are to be removed from the weld and heat affected zone in accordance with Section 2 with the exception that impact test specimens notched at the FL + 10 mm location are not required. The specimens are to be tested at a temperature of –20°C or the minimum design temperature whichever is the lower and exhibit a minimum average energy of 40 J.

3.3.3 The corrosion resistance is to be maintained in the welded condition and the following tests are to be performed to demonstrate acceptable resistance, unless agreed otherwise.

(a) A sample is to be removed from the weld and heat affected zone for micro-structural examination and is to be suitably prepared and etched so that the micro-structures of the weld and heat affected zones can be examined at a magnification of x200 or higher. The micro-structure of the weld and heat affected zone is to be examined, the percentage grain boundary carbides and intermetallic precipitates is to be reported.

(b) The ferrite content in the un-reheated weld cap and cap HAZ along with the weld root and root HAZ are to be measured and reported. The ferrite content is to be in accordance with Table 12.3.1. Where the intended construction is such that the corrosion medium is only in contact with one surface of the weld (i.e., the weld root), the ferrite determination need only be reported in that surface area.

(c) Corrosion testing is to be performed on samples removed from the weld such that both the weld and HAZ are included in the test. The critical pitting temperature is to be determined in accordance with ASTM G48 Method C and meet the requirements specified in Table 12.3.1. The cap and root surfaces are to be inspected for evidence of pitting and may require probing the surface with a needle. Pitting found on the ends of the specimen in the weld cross-section may be ignored. The use of the weight loss method for corrosion testing may be accepted subject to special consideration.

Table 12.3.1 Requirements for ferrite content and corrosion tests for duplex stainless steel test welds

Duplex Stainless Steel Material Grade	Weld and HAZ Ferrite content	Minimum Critical Pitting Temperature (CPT)
S 31260	30 to 70%	20°C
S 31803	30 to 70%	20°C
S 32550	35 to 65%	25°C
S 32750	35 to 65%	25°C
S 32760	35 to 65%	25°C

3.3.4 Where the test weld is between a grade of carbon steel and duplex stainless steel, the test requirements of 3.3.3(a) and (c) are not required and the ferrite content of the weld and the duplex heat affected zone are to be reported for information.

3.3.5 A qualification test performed on a duplex stainless steel grade may be considered acceptable for welding other duplex grades which have the same or less stringent mechanical or corrosion properties.

3.3.6 The range of heat input is not to vary by more than +10 per cent or –25 per cent from that used during testing.

3.4 Martensitic stainless steels

3.4.1 The requirements of this Section relate to the group of stainless steel materials that have a martensitic structure at ambient temperatures, *see* Table 4.5.1 in Chapter 4.

3.4.2 The results of the hardness survey results are to be reported for information purposes only.

3.4.3 A qualification test is considered acceptable only for the grade of material used in the test.

■ *Section 4*
Welding procedure tests for non-ferrous alloys

4.1 Requirements for aluminium alloys

4.1.1 The requirements for welding procedure qualification tests for aluminium alloys are to be in accordance with the general requirements of Section 2 with the following exceptions and specific requirements.

4.1.2 Non-destructive examination is to be performed in accordance with 2.5 and the assessment of results is to be in accordance with Table 12.4.1 and Table 12.4.2.

4.1.3 Acceptance of the mechanical tests is to be in accordance with Ch 11,9. Welding of the strain hardened and heat treatable aluminium alloys will generally result in a loss of tensile strength in the heat affected zone below that specified for the base materials and the tensile strength acceptance criteria to be applied is that specified for the material in the annealed or ‘as fabricated’ condition. Minimum values of tensile strength measured on the transverse tensile samples are given in Table 12.4.3.

4.1.4 Impact tests and hardness surveys are not required for aluminium alloys.

Table 12.4.1 Acceptance criteria for surface imperfections of aluminium alloys

Surface discontinuity	Classification according to ISO 6520-1	Acceptance criteria
Crack	100	Not permitted
Lack of fusion	401	Not permitted
Incomplete root penetration in butt joints welded from one side	4021	Not permitted
Surface pore	2017	$d \leq 0{,}1s$ or $0{,}1a$ max. 1,0 mm
Uniformly distributed porosity (*see* Note 1)	2012	≤ 0,5% of area
Clustered porosity	2013	Not permitted
Continuous undercut	5011	Not permitted
Intermittent undercut	5012	$h \leq 0{,}1t$ or 0,5 mm (whichever is the lesser)
Excess weld metal (*see* Note 2)	502	$h \leq 1{,}5$ mm + $0{,}1b$ or 6 mm (whichever is the lesser)
Excess penetration	504	$h \leq 4$ mm
Root concavity (*see* Note 2)	515	$h \leq 0{,}05t$ or 0,5 mm (whichever is the lesser)
Linear misalignment (*see* Notes 3 and 4)	507	$h \leq 0{,}2t$ or 2,0 mm (whichever is the lesser)

Symbols

a = nominal throat thickness of a fillet weld
b = width of weld reinforcement
d = diameter of a gas pore
h = height or width of an imperfection
s = nominal butt weld thickness
t = wall or plate thickness (nominal size)

NOTES
1. To be in accordance with EN ISO 10042.
2. A smooth transition is required.
3. The limits for linear misalignment relate to deviations from the correct position. Unless otherwise specified, the correct position is to be taken when the centrelines coincide.
4. Dimensional tolerances not specified in these Rules are to be mutually agreed between the manufacturer and the Surveyor.

4.1.5 Four side bend tests may be used in place of root and face bends where the test thickness exceeds 12 mm, and longitudinal bend tests may be used instead of transverse tests where the test weld is between different grades of alloy. Bend specimens are to be bent round a former in accordance with Table 11.9.1 in Chapter 11, with the exception that the 6000 series alloys may be bent round a former with $D/t = 7$.

4.1.6 The ranges of approval to be applied to the WPS are to be as specified for steel in 2.15 with the following exceptions:

(a) The welding positions approved are as detailed in Table 12.4.4.
(b) The aluminium alloys are grouped into three groups as follows:
  - Group A: aluminium-magnesium alloys, with Mg content ≤3,5 per cent (alloy 5754).
  - Group B: aluminium-magnesium alloys with 4 per cent ≤ Mg ≤5,6 per cent (alloys 5059, 5083, 5086, 5383 and 5456).
  - Group C: aluminium-magnesium-silicon alloys (alloys 6005A, 6061 and 6082). For each group, the qualification made on one alloy qualifies the procedure also for the other alloys in the group, with equal or lower tensile strength after welding. The qualification made on group B alloys qualifies the procedure for Group A alloys also. Approval for the range of material grades is summarised in Table 12.4.5.
(c) The qualification of a procedure carried out on a test assembly of thickness t is valid for the thickness range given in Table 12.4.6. In the case of butt joints between dissimilar thicknesses, t is the thickness of the thinner material. In the case of fillet joints between dissimilar thicknesses, t is the thickness of the thicker material. In addition to the requirements of Table 12.4.6, the range of the qualification of throat thickness of fillet welds, a, is given in Table 12.4.7. Where a fillet weld is qualified by a butt weld test, the throat thickness range qualified is to be based on the thickness of the deposited weld metal.
(d) The range of shielding gas compositions approved is to be in accordance with Table 11.9.2 in Chapter 11.
(e) A change in the brand or trade name of the filler metal from that used in the test is acceptable, provided that the proposed consumable has the same or higher strength grading.
(f) A change in post-weld heat treatment or ageing is not permitted, except that for the heat treatable alloys, artificial ageing may give approval for prolonged natural ageing.

Table 12.4.2 Acceptance criteria for internal imperfections of aluminium alloys

Internal discontinuity	Classification according to ISO 6520-1	Acceptance criteria
Crack	100	Not permitted
Lack of fusion	401	Not permitted
Incomplete penetration	402	Not permitted
Single gas pore	2011	$d \leq 0{,}2s$ or $0{,}2a$ or 4 mm (whichever is the lesser)
Linear porosity (*see* Note 2)	2014	Not permitted
Uniformly distributed porosity (*see* Note 2)	2012	$0{,}5t$ to $3t$ ≤ 1% of area > $3t$ to $12t$ ≤ 2% of area > $12t$ to $30t$ ≤ 3% of area > $30t$ ≤ 4% of area
Clustered porosity (*see* Note 1)	2013	$dA \leq 15$ mm or *wp* (whichever is the lesser)
Elongated cavity Wormhole	2015 2016	$l \leq 0{,}2s$ or $0{,}2a$ or 3 mm (whichever is the lesser)
Oxide inclusion (*see* Note 2)	303	$l \leq 0{,}2s$ or $0{,}2a$ or 3 mm (whichever is the lesser)
Tungsten inclusion	3041	$l \leq 0{,}2s$ or $0{,}2a$ or 3 mm (whichever is the lesser)
Copper inclusion	3042	Not permitted
Multiple imperfections in any cross-section	—	The sum of the acceptable individual imperfections in any cross-section is not to exceed $0{,}2t$ or $0{,}2a$ (whichever is the lesser)

Symbols

a = nominal throat thickness of a fillet weld
d = diameter of a gas pore
h = height or width of an imperfection
s = nominal butt weld thickness
t = wall or plate thickness (nominal size), in mm
wp = width of weld or width or height of cross-sectional area
dA = diameter of area surrounding gas pores
l = length of imperfection in longitudinal direction of weld

NOTES
1. For this acceptance criterion, linear porosity is to be considered as three aligned gas pores in a length of 25 mm.
2. Porosity is to be determined in accordance with ISO 10042. The requirements for a single gas pore are to be met by all the gas pores within this circle. Systematic clustered porosity is not permitted.

Table 12.4.3 Tensile strength requirements by grade for aluminium alloys

Parent material Grade (alloy designation)	Minimum tensile strength (N/mm^2)
5754	190
5086	240
5083	275
5383	290
5059	330
5456	290
6005A	170
6061	170
6082	170

Table 12.4.4 Welding procedure approval, welding positions for aluminium alloys

Test position		Positions approved
Downhand	D	D
Horizontal-vertical	X	D, X
Vertical up	Vu	D, X, Vu
Overhead	O	D, X, Vu and O

NOTE
Welding in vertical down (Vd) position is not recommended.

Table 12.4.5 Welding procedure approval, aluminium material grades approved

Material used in qualification test	Material Grades approved				
5754	5754				
5086	5086	5754			
5083	5083	5086	5754		
5383	5383	5083	5086	5754	
5059	5059	5383	5083	5086	5754
5456	5456	5383	5083	5086	5754
6005A	6005A	6082	6061		
6082	6005A	6082	6061		
6061	6005A	6082	6061		

NOTE
Approval includes all the different strained and tempered conditions in each case.

Table 12.4.6 Range of qualification for parent material thickness

Thickness of test assembly, t (mm)	Range of qualification Multi pass welds	Range of qualification All single-run or two-run (T technique) butt welds
$t \leq 3$	0,5 to 2t	0,5t to 1,1t
$3 < t \leq 20$	3 to 2t	0,5t to 1,1t
t >20	≥ 0,8t	0,5t to 1,1t

Table 12.4.7 Range of qualification of throat thickness for fillet welds

Throat thickness of test piece, a (mm)	Range of qualification
$a < 10$	0,75 a to 1,5 a
$a \geq 10$	≥ 7,5

4.2 Requirements for copper alloys

4.2.1 The requirements for welding procedure qualification tests for copper alloys are to be in accordance with the requirements for steel as given in Section 2 with the following exceptions and additions.

4.2.2 Impact tests on copper alloys are not required.

4.2.3 Hardness tests are not required for seawater service.

4.2.4 For the welding of cast copper alloys for propellers, the minimum tensile strength from the transverse tensile test is to be in accordance with Table 12.4.8.

4.2.5 Bend tests are to be performed over a diameter of former as detailed in Table 12.4.9.

Table 12.4.8 Minimum transverse tensile strengths for welded copper alloy propellers

Alloy designation	Minimum tensile strength (N/mm^2)
CU 1	370
CU 2	410
CU 3	500
CU 4	550

4.2.6 The range of approval to be applied to the WPS is to be as specified in 2.15 with the exception of the material grades which are detailed in Table 12.4.10.

Table 12.4.9 Former diameters for bend testing of copper alloy welds

Alloy designation (*see* Chapter 9)	Former diameter (*D/t*)
Cast propellers:	
CU1	4
CU2	4
CU3	6, *see* Note
CU4	6, *see* Note
Other short freezing range castings:	
Copper-Nickel 90/10	4
Copper-Nickel 70/30	4
Aluminium bronze	6
Wrought alloys (tubes and pipes):	
Copper-phosphorus	3
Aluminium-brass	3
90/10 Copper-nickel-iron	3
70/30 Copper-nickel-iron	3

NOTE
Where the qualification tests for these alloys are subjected to post-weld heat treatment the former diameter may be increased to *D/t* = 10.

Table 12.4.10 Range of approval for copper alloy material grades

Category	Alloy grade used in the qualification test	Alloy grades approved
Propellers	CU1 CU2 CU3 CU4	CU1 CU1 and CU2 CU1, CU2 and CU3 CU4 *see* Note 1
Tubes/pipes	90/10 Copper-Nickel-Iron 70/30 Copper-Nickel-Iron	90/10 Copper-Nickel-Iron 70/30 Copper-Nickel-Iron and 90/10 Copper-Nickel-Iron
Tubes/pipes *see* Note 2	Copper-Phosphorus deoxidised – arsenical Copper-Phosphorus deoxisised – non arsenical Aluminium-brass	Copper-Phosphorus deoxidised – arsenical Copper-Phosphorus deoxisised – non arsenical Aluminium-brass

NOTES
1. Where a CU3 type welding consumable has been used for the qualification test, the range of approval may also include welding of CU3.
2. These grades have limited weldability and approval to weld is subject to the materials satisfying the requirements of Table 9.3.1 in Chapter 9.

■ *Section 5* Welder qualification tests

5.1 Scope

5.1.1 The requirements of this Section relate to qualification of welders involved in welded construction associated with ships, or other marine structures, and products or components intended for use on or in these structures.

5.1.2 The requirements relate to fusion welding processes that are designated as manual, semi-automatic or partly mechanised. Special consideration will be given to other welding processes adapted from these requirements.

5.1.3 Prior to commencing production welding, the welder is to have performed a qualification test that satisfies these requirements. It is the responsibility of the manufacturer to ensure that the welder possesses the required level of skill for the work to be undertaken.

5.1.4 The qualification of welders is to be documented by the manufacturer and the records are to be available for review by the Surveyor.

5.1.5 Welder qualification tests made in accordance with EN, ISO, JIS, ASME or AWS may be considered for acceptance provided that, as a minimum, they are equivalent to, and meet the technical intent of these Rules to the satisfaction of the Surveyor.

5.2 Welder qualification test assemblies

5.2.1 The welding of the welder qualification test assembly is to simulate, as far as practicable, the conditions to be experienced in production and be witnessed by the Surveyor. The test is to be carried out on a test assembly piece and not by way of production welding.

5.2.2 The test is to simulate, as far as practicable, the welding techniques and practices to be encountered during production welding. The test assembly is to be designed to test the skill of the welder and have the shape and dimensions appropriate to the range of approval required.

5.2.3 The inspection length of the test weld is to be such as to permit the removal of all the necessary test specimens and for plate tests, but in no case is to be less than 250 mm. The test assembly is to be set in one of the positions as shown in Fig. 12.2.2 appropriate to the welding positions to be approved.

5.2.4 A welding procedure specification (WPS) is required for the execution of the qualification test and is to include the information specified in 2.2.1, as a minimum.

5.2.5 The test assembly is to be marked with a unique identification and the inspection length is to be identified prior to commencing welding. For pipe welds, the whole circumference is to be considered as the inspection length.

5.2.6 During welding of the test assembly, the welding time is to be similar to that expected under production conditions. For manual or semi-automatic processes, at least one stop and re-start in the root and in the top surface layer is to be included in the inspection length and marked for future inspection.

5.2.7 During welding of the test assembly, minor imperfections may be removed by the welder by any method that is used in production, except on the surface layer.

5.2.8 The Surveyor may stop the test if the welding conditions are not correct or if there is any doubt about the competence of the welder to achieve the required standard.

5.3 Examination and testing

5.3.1 Each completed test weld is to be examined and tested in accordance with the requirements of Table 12.5.1.

5.3.2 Visual examination is to be performed in the as welded state prior to any other assessment.

5.3.3 For plate butt welds, fracture testing may be used in place of radiography.

5.3.4 Where a backing strip has been used, it is to be retained for non-destructive examinations, but is to be removed prior to performing any bend or fracture tests.

5.3.5 Where fracture tests are required, they are to sample as much of the inspection length as practicable and the test assembly may be cut into several test specimens to achieve this. Testing is to be performed as shown in Figs. 12.5.1(a) or 12.5.1(b).

5.3.6 For butt weld tests in aluminium alloys both radiography and bend tests are required.

5.3.7 When bend tests are required, 2 root and 2 face bends are to be tested and where the test thickness exceeds 12 mm, these may be substituted by 4 side bends specimens. The diameter of former to be used is to be in accordance with that specified for welding procedure qualification testing given in 2.7.6(a).

5.3.8 Where macro examination is required, the specimen is to be polished and etched to reveal the weld runs and heat affected zones, and be examined at a magnification between x5 and x10.

Table 12.5.1 Welder qualification test requirements

Examination type	Butt welds	Fillet welds	Pipe branch welds
Visual	100%	100%	100%
Surface crack detection	*See* Note 1	100%	100%
Radiography	100% *See* Notes 2 and 6	Not required	Not required
Bend tests	4 required *See* Notes 3 and 6	Not required	Not required
Fracture tests	Not required	1 required *See* Note 4	Not required
Macro	Not required	1 required *See* Note 4	4 required *See* Note 5

NOTES
1. Surface crack detection examination may be required by the Surveyor in order to clarify the acceptability of any weld feature.
2. Radiography may be replaced by ultrasonic examination for carbon and low alloy steels where the thickness exceeds 8 mm.
3. Bend tests are required for gas metal arc welding with solid wire (GMAW) and oxy-acetylene welding.
4. The fracture test may be replaced with 4 macro sections equally spaced along the inspection length.
5. Macro-sections are to be separated by 90° measured around the abutting pipe member.
6. Radiography and bend tests are required for tests in aluminium alloys.

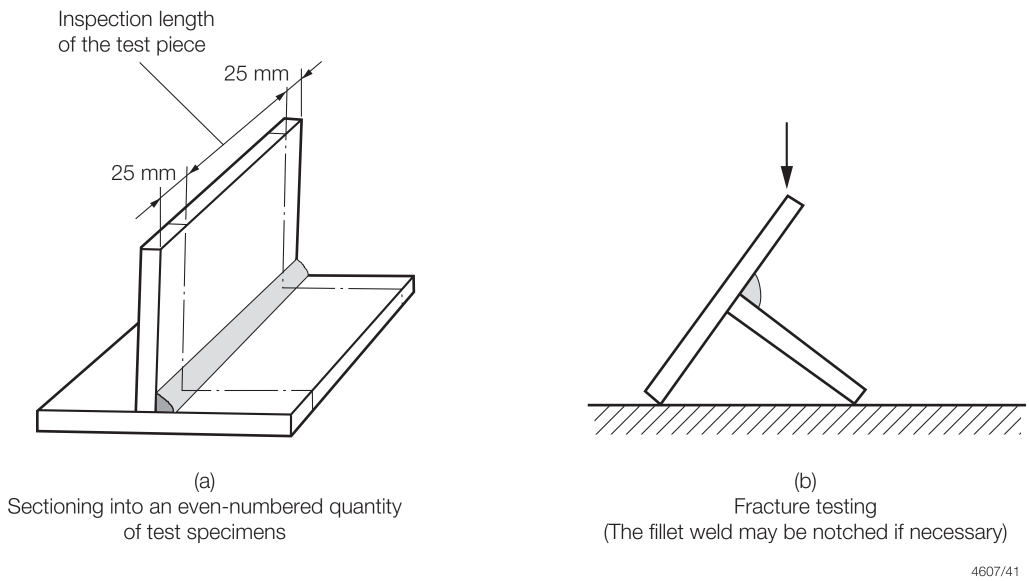


Fig. 12.5.1(a) Preparation and fracture testing of test specimens for a fillet weld in plate

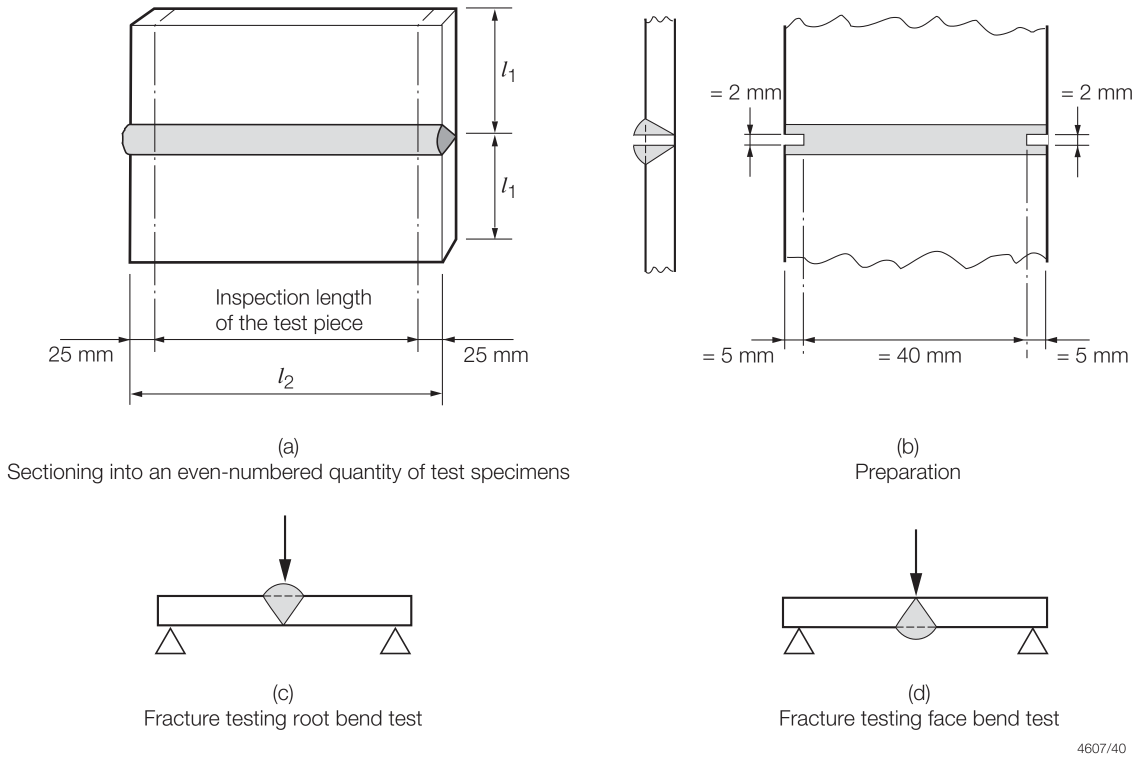


Fig. 12.5.1(b) Preparation and fracture testing of test specimens for a butt weld in plate

5.4 Acceptance criteria

5.4.1 The acceptance criteria are to be in accordance with 2.5.5.

5.4.2 Fracture tests and macro-sections are to be assessed in accordance with the non-destructive examination acceptance criteria.

5.4.3 Bend tests are considered acceptable if after bending through an angle of at least 180°, there are no defects on the tension side of the specimen greater than 3 mm in any direction.

5.5 Failure to meet requirements

5.5.1 Where a macro-section fails to meet requirements, one additional specimen may be removed from the test assembly and examined.

5.5.2 Where a bend or fracture test specimen fails to meet requirements, two additional specimens may be prepared from the same test assembly. If there is insufficient material, the welder may be permitted to weld an additional assembly to the same WPS, at the discretion of the Surveyor.

5.5.3 Where any of the additional test specimens fails to satisfy the requirements, the test will be considered as not meeting the requirements.

5.5.4 Where a test fails to comply with the acceptance criteria, the welder may be permitted to weld a second test piece. If this does not meet requirements, the welder is to be considered as not being capable of achieving the requirements.

5.6 Range of approval

5.6.1 Upon successful completion of all the necessary examinations and tests, the welder is to be considered qualified. The essential variables and the range of welding conditions for which the welder is considered approved are specified in the following paragraphs.

5.6.2 Welding variables such as preheat, interpass temperature, heat input and current type are not considered welder qualification variables. However, if the WPS used for testing specify these, they are to be included in the test and the welder is expected to follow the specific instructions.

5.6.3 Where the WPS used for the welder qualification test specifies post weld heat treatment, this need not be applied to the test weld unless bend tests are required and the material exhibits low ductility in the as welded condition.

5.6.4 The qualification test performed by a manufacturer is only applicable to workshops under the same technical control and quality system as that used for the test.

5.6.5 The welding process used in the qualification test is the process approved. However, it is possible for the welder to use more than one process in the test and the range of approval that may be applied to each will be within the limits of the essential variables appropriate to the part of the test where each welding process was used.

5.6.6 Material types are to be grouped as shown in Table 12.5.2 for welder qualifications. A qualification test performed on one material from a group will permit welding of all other materials within the same group. In addition, qualification on one group of materials may confer approval to weld other groups as shown in Table 12.5.3.

5.6.7 A qualification test performed on one thickness will confer approval to weld other thicknesses as specified in Table 12.5.4. Where welding is required between materials of different thickness, the reference thickness for approval purposes is to be the lesser thickness.

5.6.8 A qualification test performed on plate confers approval to weld on pipes having an outside diameter greater than 500 mm in a fixed position (*see* Table 12.5.5 and Table 12.5.6).

5.6.9 A qualification test performed using a specific diameter of pipe will give approval to weld other diameters as shown in Table 12.5.5. For branch welds, the diameter upon which approval is based is to be the branch member.

5.6.10 A qualification test performed on a butt weld may be considered as giving approval for fillet welds.

5.6.11 A butt qualification test welded from one side, with the root unsupported (i.e., no backing), will give approval for welds made from both sides with or without back gouging or grinding, but not vice versa.

5.6.12 A qualification test performed in one position will give approval to weld in other positions as shown in Table 12.5.6.

5.6.13 For manual metal arc welding with covered electrodes, a qualification test performed using an electrode with one type of coating will only be approved for welding with that type of coating. However, a qualification test performed using a basic low hydrogen type coating will confer approval to use electrodes with rutile coatings.

5.6.14 For gas shielded welding processes that use a single component shielding gas, no change to the gas composition is permitted from that tested. Where the test has used a two component shielding gas, a change in the ratio of component gases is permitted, provided that one of the components is not reduced to zero. Where the test has used a three component shielding gas, changes are permitted in the ratio of component gases and the gas with the smallest ratio may be reduced to zero, provided this does not change the shielding gas from an active one to an inert one or vice versa. In addition, where a change in shielding gas composition requires a different welding method or technique to be employed, a new qualification test will be required.

5.6.15 A change of welding flux from that used for the test is permitted.

Table 12.5.2 Welder qualification materials groupings

Material group	Material description	Typical LR Grades	Rules for Material references
WQ 01	Low carbon unalloyed, C/Mn, or Low alloyed steels (Re ≤ 360 N/mm^2)	A, B, D and E AH to FH32 and 36 Boiler 510FG and lower LT-AH to FH32 and 36 U1 and U2 Steel castings Steel pipes	Ch 3,2 Ch 3,3 Ch 3,4 Ch 3,6 Ch 3,9 and Ch 10 Ch 4,2, 3, 6 and 7 Ch 6,2, 3, 4 and 6
WQ 02	Cr-Mo, or Cr-Mo-V creep resisting steels	13CrMo45 and 11CrMo910 1Cr½Mo and 2¼Cr1Mo ½Cr½Mo¼V	Ch 3,4 Ch 4,6 and Ch 6,2, 3 and 6 Ch 4,6 and Ch 6,2
WQ 03	High strength fine grained, Normalised or quenched, or Tempered structural steels (2,0 – 5% Ni, with Re > 360 N/mm^2)	AH to FH40 to 69 LT-AH to LT-FH40 1½ , 3½ Ni steels and castings U3, R3, R3S and R4	Ch 3,3 and 10 Ch 3,6 Ch 3,6, Ch 4,7 and Ch 6,4 Ch 3,9 and Ch 10
WQ 04	Ferritic, or martensitic stainless steels (12 to 20% Cr)	13% Cr (martensitic)	Ch 4,5 (martensitic)
WQ 05	Ferritic low temperature steels	5Ni and 9Ni	Ch 3,6
WQ 011	Ferritic-austenitic stainless steels, Austenitic stainless steels, or Cr-Ni steels	304, 316, 317, 321 and 347 S31260, S31803, S32550 and S32750	Ch 3,7 and 8 Ch 4,8 and Ch 6,5
WQ 22a	Aluminium alloy – Non-heat treatable Mg < 3,5%	5754	Chapter 8
WQ 22b	Aluminium alloy – Non-heat treatable 3,5% < Mg < 5,6%	5083 and 5086	Chapter 8
WQ 23	Aluminium alloy – Heat treatable	6005-A, 6061 and 6082	Chapter 8
WQ 30	Copper alloys for propellers – Manganese bronze	Cu1	Ch 9,1
WQ 31	Copper alloys for propellers – Nickel- manganese bronze	Cu2	Ch 9,1
WQ 32	Copper alloys for propellers – Nickel- aluminium bronze	Cu3	Ch 9,1
WQ 33	Copper alloys for propellers – Manganese-aluminium bronze	Cu4	Ch 9,1
WQ 34	Copper alloys for tubes – Copper phosphorus	Deoxidised – non-arsenical and arsenical	Ch 9,3
WQ 35	Copper alloys for tubes – Aluminium brass	Aluminium brass	Ch 9,3
WQ 36	Copper alloys for tubes – Copper- nickel-iron	70/30 Cu/Ni and 90/10 Cu/Ni	Ch 9,3

5.7 Welders qualification certification

5.7.1 All the relevant conditions used during the test are to be entered on the welder's qualification certificate along with the permitted range of approval.

5.7.2 If the Surveyor is satisfied that the welder has demonstrated the appropriate level of skill and all tests are satisfactory, the Surveyor will endorse the certificate verifying that the details contained on it are correct and that the test welds were prepared, welded and tested in accordance with the specified Rules, Codes or Standards.

5.7.3 The welder is considered to be approved for an initial validity period of 2 years. The welder is considered to have retained the qualification subject to the manufacturer confirming every 6 months that the welder has used the welding process with acceptable performance in the preceding 6 months.

5.7.4 After 2 years, the Surveyor may extend the validity of the approval for another period of two years provided that records or documented evidence is made available confirming acceptable welding performance, within the original range of approval, without a break exceeding 6 months. The Surveyor will signify acceptance of the extension to the validity by endorsing the certificate.

Table 12.5.3 Welder qualification, range of approval for material groups

Material group used for testing	Material groups approved to weld			
WQ 01	WQ 01			
WQ 02	WQ 01	WQ 02		
WQ 03	WQ 01	WQ 02	WQ 03	
WQ 04	WQ 01	WQ 02	WQ 04	
WQ 05	WQ 05			
WQ 11	WQ 11	WQ 05, *see* Note	WQ 04, *see* Note	
WQ 22a	WQ 22a	WQ 22b		
WQ 22b	WQ 22a	WQ 22b		
WQ 23	WQ 22a	WQ 22b	WQ 23	
WQ 30	WQ 30	WQ 31	WQ 32	WQ 33
WQ 31	WQ 30	WQ 31	WQ 32	WQ 33
WQ 32	WQ 30	WQ 31	WQ 32	WQ 33
WQ 33	WQ 30	WQ 31	WQ 32	WQ 33
WQ 34	WQ 34	WQ 35		
WQ 35	WQ 34	WQ 35		
WQ 36	WQ 36			

NOTE
Provided an austenitic welding consumable compatible with material group WQ 11 is used.

Table 12.5.4 Welder qualification, range of approval for material thickness

Material type	Test piece thickness (mm)	Range approved, *see* Note (mm)
Steel and copper alloys	$t \leq 3$ $3 < t \leq 12$ $t > 12$	t to $2t$ 3,0 to $2t$ ≥ 5,0
Aluminium alloys	$t \leq 6$ $6 < t \leq 15$ $t > 40$ mm	0,7 to $2{,}5t$ $6{,}0 < t \leq 40{,}0$ 41 to $2t$

NOTE
For oxy-acetylene welding the maximum thickness is limited to 1,5 t.

Table 12.5.5 Welder qualification, diameter range of approval for pipes and hollow sections

Material type	Test piece diameter (mm)	Range approved (mm)
Steel and copper alloys	$D \leq 25$ $25 < D \leq 150$ $D > 150$ Plate, *see* Note 2	D to $2D$ $0{,}5D$ to $2D$, *see* Note 1 $\geq 0{,}5D$ ≥ 500
Aluminium alloys	$D \leq 125$ $D > 125$ Plate, *see* Note 2	$0{,}25D$ to $2D$ $\geq 0{,}5D$ ≥ 500

NOTES
1. Subject to 25 mm minimum diameter.
2. Plate qualification will approve welding on pipes greater than 150 mm diameter when the pipe is rotated.

Table 12.5.6 Welding position ranges for welder qualification

Test weld conditions		Positions qualified			
		Plate		Pipe, *see* Note 1	
Type of weld	Test position	Butt weld	Fillet weld	Butt weld	Fillet weld
Plate butt, *see* Note 5	D	D	D	D	D
	X	D,X	D, X	D	D, X
	Vu	D, Vu	D, X, Vu	D	D, Vu
	Vd	Vd	Vd	–	–
	O	D, X, Vu, O	D, X, Vu, O	D	D, X, Vu, O
Plate Fillet, *see* Note 5	D	–	D	–	D
	X	–	D, X	–	D, X
	Vu	–	D, X, Vu	–	D, X, Vu
	Vd	–	Vd	–	–
	O	–	D, X, Vu, O	–	D, X, Vu, O
Pipe butt	D	D	D, X	D	D, X
	X	D, X	D, X	D, X	D, X
	D+Vu+O, *see* Note 3	D, Vu, O	D, X, Vu, O	D, Vu, O	D, X, Vu, O
	D+Vd+O, *see* Notes 2 and 3	Vd	Vd	Vd	Vd
	Axis at 45°, *see* Note 4, Travel Vu	D, X, Vu, O	D, X, Vu, O	D, X, Vu, O	D, X, Vu, O
	Axis at 45°, *see* Notes 2, 3 and 4, Travel Vd	Vd	Vd	Vd	Vd
Pipe fillet	D	–	D	–	D
	X	–	D, X	–	D, X
	D+Vu+O *see* Note 3	–	D, X, Vu, O	–	D, X, Vu, O
	D+Vd+O *see* Note 3	–	Vd	–	Vd

NOTES
1. Pipe D position means pipe in horizontal position and rotated, *see* Fig. 12.2.2(b) and Fig. 12.2.2(d).
2. Vd position not usually recommended for pipe welds less than 500 mm diameter.
3. Pipe fixed with axis in the horizontal position (e.g. ASME 5G).
4. Pipe fixed with axis at 45° to the horizontal (e.g. ASME 6G).
5. Plate qualification tests confers approval to weld pipes with diameter greater than 500 mm.

5.7.5 Where there is any reason to question the welder's ability, or there is a lack of continuity in the use of the welding process, or insufficient recorded evidence of acceptable weld performance, the welder is to perform a new qualification test.

5.7.6 Where the manufacturer has existing welders that have previously performed qualification tests, these may be considered for acceptance provided they satisfy the above requirements and the tests have been performed in the presence of an independent examiner that is acceptable to the Society.

5.7.7 Not withstanding the above, the Surveyor may at any time request a review of a welder's qualification records. If there is any reason for doubt concerning the skill of the welder, the Surveyor may withdraw the qualification and require a re-qualification test to be performed.

Requirements for Welded Construction

Section

■ *Section 1* General welding requirements

1.1 Scope

1.1.1 This Chapter specifies requirements for fabrication and welding during construction and repair of ships or other marine structures, and their associated pressure vessels, machinery, equipment, components and products intended for use in these structures.

1.1.2 The requirements for fabrication and welding during construction and repair of tanks intended for transport or storage of liquefied gases are located in the *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquefied Gases in Bulk* or the *Rules and Regulations for the Classification of a Floating Offshore Installation at a Fixed Location*, as appropriate.

1.1.3 The requirements relate to fusion welding. Special consideration will be given to the use of other welding processes based on these requirements.

1.1.4 It is the responsibility of the manufacturer to ensure compliance with all aspects of these Rules and inform the Surveyor of any deviations that have occurred. All deviations are to be recorded as non-compliances along with the corrective actions taken and failure to do this is considered to render the fabrication to be in non-compliance with the Rules.

1.1.5 Welded constructions that comply with National or International specifications may be accepted to the satisfaction of the surveyor, provided that these specifications give reasonable equivalence to the requirements of this Chapter.

1.1.6 All welded construction is to be to the satisfaction of the Surveyor.

1.2 Design

1.2.1 Prior to commencing any work, the component to be manufactured is to be subjected to design review and approval in accordance with the Rule requirements.

1.2.2 The material characteristics that are affected by welding, particularly the loss of strength (e.g., in precipitation or strain hardened aluminium alloys) are to be considered in the design. The weld joints in such materials are to be arranged such that they are in areas of lower stress.

1.3 Materials

1.3.1 Materials used in welded construction are to be manufactured at works approved by LR. The use of materials from alternative sources will be subject to agreement of the Surveyor and satisfactory verification testing.

1.3.2 Materials are to be supplied and certified in accordance with the requirements of Chapters 1 to 10 of these Rules.

1.3.3 Materials used in welded construction are to be readily weldable and are to have proven weldability, unless requirements are agreed with LR in advance.

1.3.4 Where the construction details are such that materials are subject to through-thickness strains, consideration is to be given to using material with specified through-thickness properties as specified in Ch 3,8.

1.3.5 When ordering materials for construction, consideration is to be taken of the possible degradation of properties during fabrication or post-weld heat treatment. Where these materials are used, consideration is to be given to additional test requirements being specified to the supplier.

1.3.6 The identity of materials is to be established by way of markings etc, during fabrication, so that traceability to the original manufacturer's certificate is maintained.

1.3.7 Pre-fabrication shop primers may be applied prior to welding, provided that they are of an approved type and have been tested to demonstrate that they have no deleterious effects on the completed weld.

1.3.8 Where it is proposed to weld forgings and/or castings, full details of the joint details, welding procedures and post-weld heat treatments are to be submitted for consideration.

1.4 Requirements for manufacture and workmanship

1.4.1 The welding workshops are to be assessed by the Surveyor for their capability to produce work of the required quality in accordance with the requirements specified for the type of construction, *see* Sections 2 to 5.

1.4.2 Where structural components are to be assembled and welded in works sub-contracted by the builder, the Surveyor is to inspect the sub-contractor's works to ensure that compliance with the requirements of this Chapter is achieved.

1.4.3 The manufacturer is to provide a system of regular supervision of all welding, by suitably qualified and experienced personnel.

1.4.4 Welding is to be performed in covered workshops as far as practicable. Where this is not possible, provision is to be made in the welding area to give adequate protection from wind, rain and cold, etc.

1.4.5 Where required, arrangements are to be such as to permit adequate ventilation and access for preheating, and for the satisfactory completion of all welding operations.

1.4.6 The location of welding connections and sequences of welding are to be arranged to minimise distortion and the build up of residual stresses. Welded joints are to be so arranged as to facilitate the use of downhand welding wherever possible.

1.4.7 In the case of repairs to existing structures or components, care is to be exercised when attaching fit-up aids by welding to ensure that the base materials in way of the attachments are of weldable quality.

1.4.8 In order to prevent cross-contamination of different material types, the welding of carbon steel materials is to be in areas segregated from that used for either austenitic or non-ferrous materials, *see* Section 7.

1.5 Cutting of materials

1.5.1 Materials may be cut to the required dimensions by thermal means, shearing or machining in accordance with the manufacturing drawings or specifications.

1.5.2 Cold shearing is not to be used on materials in excess of 25 mm thick. Where used, the cut edges that are to remain un-welded are to be cut back by machining or grinding for a minimum distance of 3 mm.

1.5.3 Material, which has been thermally cut, is to be free from excessive oxides, scale and notches.

1.5.4 All cut edges are to be examined to ensure freedom from material and/or cutting defects. Visual examination may be supplemented by other techniques.

1.5.5 Thermal cutting of alloy and high carbon steels may require the application of preheat, and special examination of these cut edges will be required to ensure no cracking. In these cases, the cut edge is to be machined or ground back a distance of at least 2 mm, unless it has been demonstrated that the cutting process has not damaged the material.

1.5.6 Any material damaged in the process of cutting is to be removed by machining, grinding or chipping back to sound metal. Weld repair may only be performed with the agreement of the Surveyor.

1.6 Forming and bending

1.6.1 Plates, pipes, etc., may be formed to the required shape by any process which does not impair the quality of the material.

1.6.2 Where hot forming is employed or during cold forming where the material is subjected to a permanent strain exceeding 10 per cent or formed to a diameter to thickness ratio less than 10, tests are required to be performed to demonstrate that the material properties remain acceptable.

1.6.3 As far as practicable, forming is to be performed by the application of steady continuous loading using a machine designed for that purpose. The use of hammering, in either the hot or cold condition is not to be employed.

1.6.4 Material may be welded prior to forming or bending, provided that it can be demonstrated that the weld mechanical properties are not impaired by the forming operation. All welds subjected to bending are to be inspected on completion to ensure freedom from surface breaking defects.

1.7 Assembly and preparation for welding

1.7.1 Excessive force is not to be used in fairing and closing the work. Where excessive root gaps exist between surfaces or edges to be joined, corrective measures are to be adopted.

1.7.2 Provision is to be made for retaining correct alignment during welding operations in accordance with the approved manufacturing specifications and welding procedures.

1.7.3 Tack welds are to be avoided as far as practicable. When used, tack welds are to be of the same quality as the finished welds, made in accordance with approved welding procedures, and where they are to be retained as part of the finished weld, they are to be clean and free from defects.

1.7.4 Generally, tack welds are not to be applied in lengths of less than 30 mm for mild steel grades and aluminium alloys, and 50 mm for higher tensile steel grades. Smaller tack welds may be accepted for steels, provided that the carbon equivalent of the materials being welded is not greater than 0,36 per cent.

1.7.5 Where deep penetration welding is used (*see* 2.4.6), welding procedure tests are to demonstrate that the specified degree of penetration is achieved in way of tack welds left in place.

1.7.6 Where temporary bridge pieces or strong-backs are used, they are to be of similar materials to the base materials and welded in accordance with approved welding procedures.

1.7.7 Any fit-up aids and tack welds, where welded to clad materials, are to be attached to the base material and not to the cladding.

1.7.8 Surfaces of all parts to be welded, are to be clean, dry and free from rust, grease, debris and other forms of contamination.

1.7.9 When misalignment of structural members either side of bulkheads, decks etc., exceeds the agreed tolerance, the misaligned item is to be released, realigned and re-welded in accordance with an approved procedure.

1.8 Welding equipment and welding consumables

1.8.1 Welding plant and equipment is to be suitable for the purpose intended and properly maintained, taking into account relevant safety precautions.

1.8.2 Suitable means of measuring the welding parameters (i.e. current, voltage and travel speed) are to be available. Electrical meters are to be properly maintained and have current calibrations.

1.8.3 Welding consumables are to be suitable for the type of joint and grade of material to be welded, and in general, are to be LR Approved in accordance with Chapter 11.

1.8.4 Special care is to be taken in the distribution, storage and handling of all welding consumables. They are to be kept in heated dry storage areas with a relatively uniform temperature in accordance with the consumable manufacturer's recommendations. Condensation on the metal surface (e.g., wire electrodes and studs) during storage and use is to be avoided.

1.8.5 Prior to use, welding consumables are to be dried and/or baked in accordance with the consumable manufacturer's recommendations.

1.8.6 Satisfactory storage and handling facilities for consumables are to be provided close to working areas and the condition of welding consumables are to be subject to regular inspections.

1.9 Welding procedure and welder qualifications

1.9.1 Welding procedures are to be developed by the manufacturer for all welding, include weld repairs, and are to be capable of achieving the mechanical property requirements and non-destructive examination quality appropriate to the work being undertaken.

1.9.2 Welding procedures are to be established for the welding of all joints and are to be qualified by testing in accordance with Chapter 12. The welding procedures are to give details of the welding process, type of consumable, joint preparation, welding position and filler metals to be used.

1.9.3 The proposed welding procedures are to be approved by the Surveyor prior to construction.

1.9.4 All welders and welding operators are to be qualified in accordance with the requirements of Chapter 12. Qualification records to demonstrate that welding personnel have the skills to achieve the required standard of workmanship are to be available to the Surveyor.

1.10 Welding during construction

1.10.1 Materials to be assembled for welding are to be retained in position by suitable means such that the root gaps and alignment are in accordance with the approved manufacturing specifications and welding procedures.

1.10.2 Surfaces of all parts to be welded, are to be clean, dry and reasonably free from rust, scale and grease.

1.10.3 Pre-heat is to be applied, as specified in the approved welding procedure, for a distance of at least 75 mm from the joint preparation edges. The method of application and temperature control are to be such as to maintain the required level throughout the welding operation.

1.10.4 When the ambient temperature is 0°C or less, or where moisture resides on the surfaces to be welded, due care is to be taken to pre-heat the joint to a minimum of 20°C, unless a higher pre-heat temperature is specified.

1.10.5 Where tack welds are to be removed from the root of the weld joint, this is to be carried out such that the surrounding material and joint preparation is not damaged.

1.10.6 The welding arc is to be struck on the parent metal which forms part of the weld joint or on previously deposited weld metal.

1.10.7 Where the welding process used is slag forming (e.g., manual metal arc, submerged arc, etc.) each run of deposit is to be cleaned and free from slag before the next run is applied.

1.10.8 Full penetration welds are to be made from both sides of the joint as far as practicable. Prior to welding the second side, the weld root is to be cleaned, in accordance with the requirements of the approved welding procedure, to ensure freedom from defects. When air-arc gouging is used, care is to be taken to ensure that the ensuing groove is slag and oxide free and has a profile suitable for welding.

1.10.9 Where welding from one side only, care is to be exercised to ensure the root gap is in accordance with the approved welding procedure and the root is properly fused.

1.10.10 Particular care is to be exercised in welding in the vertical position with direction of travel downward (Vd) to avoid welding defects. The use of solid wire gas metal arc (GMAW) process in the vertical down position is to be avoided.

1.10.11 Welding is to proceed systematically with each welded joint being completed in correct sequence without undue interruption.

1.10.12 After welding has been stopped for any reason, care is to be taken in restarting to ensure that the previously deposited weld metal is thoroughly cleaned of slag and debris, and preheat has been re-established.

1.10.13 Care is to be taken to avoid stress concentrations such as sharp corners or abrupt changes of section, and completed welds are to have an even contour, blending smoothly with the base materials. The weld shape and size is to be in accordance with that specified in the approved drawings or specifications.

1.10.14 Welded temporary attachments used to aid construction are to be removed carefully by grinding, cutting or chipping. The surface of the material is to be finished smooth by grinding followed by crack detection.

1.10.15 Where fabricated and welded components require to be machined, all major welding operations are to be completed prior to final machining.

1.10.16 Welding to parts which are subjected to rotating fatigue (e.g., shafts) is not generally permitted.

1.10.17 Welding onto parts that have been hardened for wear resistance or strength (e.g., gear teeth) is not permitted.

1.10.18 Where welding of clad ferritic steel plates is to be undertaken, the clad materials are to be ground back from the prepared edge by at least 10 mm. In general, the ferritic materials are to be welded prior to welding of the cladding material.

1.11 Non-destructive examination of welds

1.11.1 Non-destructive examinations are to be made in accordance with a definitive written procedure prepared and endorsed by a person qualified according to a Nationally Recognised Scheme with a grade equivalent to Level III qualification of ISO 9712, SNT-TC-1A, EN473, or ASNT Central Certification Program (ACCP). As a minimum, the procedure will identify personnel qualification levels, NDE datum and identification system, extent of testing, methods to be applied with technique sheets, acceptance criteria and reporting requirements. These procedures are to be reviewed by the Surveyor. *See* Ch 1,5.

1.11.2 Non-destructive examinations are to be undertaken by personnel qualified according to a Nationally Recognised Scheme with a grade equivalent to Level II qualification of ISO 9712, SNT-TC-1A, EN473 or ASNT Central Certification Program (ACCP). Operators qualified to Level I of the above schemes (or equivalent recognised by LR) may be engaged in testing under the supervision of personnel qualified to Level II or III (or equivalent recognised by LR). Personnel qualifications are to be verified by certification.

1.11.3 Effective arrangements are to be provided by the manufacturer for the inspection of finished welds to ensure that all welding, and where necessary, all post-weld heat treatment, has been satisfactorily completed.

1.11.4 Welds are to be clean and free from paint at the time of visual inspection unless specified otherwise in the following Sections.

1.11.5 The weld surface finish is to ensure accurate and reliable detection of defects. Where the weld surface is irregular or has other features likely to interfere with the interpretation of non-destructive examination, the weld is to be ground or machined.

1.11.6 Prior to inspection, welded temporary attachments and lifting eyes used to aid construction are to be removed carefully by grinding, cutting or chipping or other approved means. The surface of the material is to be finished smooth by grinding followed by crack detection. Any defects caused in the removal process are to be repaired and re-inspected.

1.11.7 For welds in steels with specified yield strength up to 400 N/mm^2, and with carbon equivalent less than or equal to 0,41 per cent, NDE may be performed as soon as the test assembly has cooled to ambient temperature. For other steels, NDE is to be delayed for a period of at least 48 hours after the test assembly has cooled to ambient temperature.

1.11.8 Non-destructive examinations are to be performed in accordance with the requirements of the Rules. Examinations are to be in accordance with agreed written procedures prepared by the manufacturer or ship builder.

1.11.9 The Surveyor may request additional inspections where there is reason to question the quality of workmanship, or where the weld is part of a complicated fabrication where there is high restraint or high residual stresses.

1.11.10 Welds are to be examined after completion of any post-weld heat treatment.

1.11.11 Where weld defects are discovered, the full extent is to be ascertained by applying additional non-destructive examinations where required. Unacceptable defects are to be completely removed and, where necessary, weld repaired in accordance with the relevant Sections of this Chapter. The repairs are to be re-inspected using the same technique as the original inspection.

1.11.12 Results of non-destructive examinations are to be recorded and evaluated by the constructor on a continual basis in order that the quality of welding can be monitored. These records are to be available to the Surveyor.

1.11.13 The constructor is to be responsible for the review, interpretation, evaluation and acceptance of the results of NDE. Reports stating compliance or otherwise with the criteria established in the inspection procedure are to be issued. Reports are to comply, as a minimum, with the requirements of Ch 1,5.

1.11.14 The extent of applied non-destructive examination is to be increased when warranted by the analysis of previous results.

1.12 Routine weld tests

1.12.1 Routine or production weld tests may be specified as a means of monitoring the quality of the welded joints. This type of quality control test is generally specified for pressure vessel and LNG construction but may be used for other types of welded fabrication.

1.12.2 Routine weld tests may be requested by the Surveyor where there is reason to doubt the quality of workmanship.

1.12.3 Where routine test welds have been agreed, they are to be performed in accordance with the general requirements for the type of construction, *see* Sections 3 and 4.

1.13 Rectification of material defects

1.13.1 Repair of defects found in base materials is not to be carried out without the prior approval of the Surveyor.

1.13.2 In general, surface defects in the material may be removed by grinding, chipping, etc., provided the remaining material thickness is not reduced below the minimum thickness tolerance, and the area is ground to blend in smoothly with the surrounding material.

1.13.3 Confirmation that the defect has been removed is required by performing visual examination, augmented by either magnetic particle or dye penetrant examination techniques.

1.13.4 Surface defects, which cannot be repaired by the above method, may be repaired by welding where permitted by Chapters 3 to 9. Such repairs are to be performed in accordance with the requirements of this Section and those specified in Chapters 3 to 9.

1.13.5 Any defects in the structure resulting from the removal of temporary attachments are to be prepared, efficiently welded and ground smooth so as to achieve a defect free repair.

1.14 Rectification of distortion

1.14.1 Fairing, by linear or spot heating, to correct distortions due to welding, may be carried out. In order to ensure that the properties of the material are not adversely affected, approved procedures are to be utilised. On completion of such processes, visual examination of all heat affected areas in the vicinity is to be carried out to ensure freedom from cracking.

1.14.2 When misalignment of members exceeds the agreed tolerance, the misaligned item is to be cut apart, realigned and re-welded in accordance with an approved procedure.

1.15 Rectification of welds defects

1.15.1 Where repairs are extensive the manufacturer is to investigate the reason for the defects and take the necessary actions to prevent recurrence. In addition, consideration is to be given to the sequence of repairs and to providing temporary supports to prevent misalignment or collapse.

1.15.2 Cracks are to be reported to the Surveyor and the cause established prior to undertaking weld repairs.

1.15.3 Defects may be removed by grinding, chipping or thermal gouging. Where thermal gouging is used, the repair groove is to be subsequently ground clean to remove oxides and debris. The groove is to have a profile suitable for welding.

1.15.4 Prior to commencing repair welding, it is to be confirmed that no defect exists on the prepared surface by performing visual examination, augmented by either magnetic particle or dye penetrant examination techniques.

1.15.5 Repair welding is to be performed using approved welding procedures.

1.15.6 Completed repairs are to be re-examined by the non-destructive examination method(s) that detected the original defect and are to confirm that the original defect has been removed.

1.15.7 Where the component or structure has been subjected to post-weld heat treatment prior to weld repair, this is to be repeated after completion of all repair welding.

1.15.8 Where non-destructive examination reveals that the original defect has not been successfully removed, one more repair attempt may be performed.

1.15.9 The manufacturer is to monitor the quality of welding and maintain records of welding repairs and take the necessary corrective actions where repair rates are outside normal limits.

1.16 Post-weld heat treatment

1.16.1 On completion of welding, post-weld heat treatment may be required depending on the type of welded construction, the material type and thickness as specified by the relevant Parts or Sections of the Rules.

1.16.2 In general, heat treatment after welding is to be a stress relief treatment in order to reduce residual stresses introduced by welding and is generally applicable to ferritic steels. Where other types of heat treatment (e.g., normalising, solution annealing) are proposed, demonstration of acceptable mechanical properties of the weldment are to be confirmed by a welding procedure test which includes a simulated heat treatment.

1.16.3 Parts are to be properly prepared for heat treatment. Machined surfaces (e.g., flange faces, screw threads, etc.) are to be protected against scaling and sufficient temporary supports provided to prevent distortion or collapse of the structure.

1.16.4 Details of the heat treatment to be applied, soaking time and temperature, heating and cooling rates, etc., are to be submitted for review prior to commencing.

1.16.5 Post-weld heat treatment is to be carried out in a purpose built furnace which is efficiently maintained. In special cases, where the configuration of the component is such that thermal stresses during heating and cooling can be minimised, local post-weld heat treatment may be used. This would not normally apply to the complex geometry of cast materials during manufacture within the foundry environment.

1.16.6 In all cases, the heat treatment facilities and arrangements are to be capable of controlling the temperature throughout the heat treatment cycle and adequate means of measuring and recording the component temperature are to be provided. Thermocouples are to be attached so they are in contact with the component.

1.16.7 Unless specified otherwise, stress relief heat treatment is to be carried out by means of controlled heating from 300°C, to the soak temperature, holding within the prescribed soaking temperature range for the time specified (usually 1 hour per 25 mm of weld thickness) followed by controlled cooling to below 300°C.

1.16.8 Where post-weld stress relief is specified for welded constructions that contain joints between different materials (e.g. ferritic to austenitic steels), the details of the materials, welding procedures and heat treatment cycle to be applied are to be submitted for special consideration and approval.

1.16.9 Non-destructive examination of welds is to be performed after completion of any heat treatment.

1.17 Certification

1.17.1 Products or components are not to be considered complete until all the requirements of the construction specification have been met and all activities have been completed.

1.17.2 Upon completion of the works, the manufacturer is to provide documentation which indicates that:

(a) All welds are complete and there are no outstanding repairs.
(b) The appropriate post-weld heat treatments have been performed.
(c) Appropriate destructive tests have been performed.
(d) Proof testing of welds has been performed.

1.17.3 Before the test certificates or shipping statements are signed by the Surveyor, the manufacturer is required to provide a written declaration stating that the product is in accordance with the requirements of 1.17.2.

■ *Section 2*
Specific requirements for ship hull structure and machinery

2.1 Scope

2.1.1 The requirements of this Section apply to the construction of ships, including hull structure, superstructure and deckhouses, components forming part of the ship structure and its machinery (excluding pressure equipment and piping, *see* Section 4). These requirements are in addition to the general welding requirements specified in Section 1.

2.1.2 The shipyard and manufacturer's works are to be assessed to give assurance that they have the facilities, equipment, personnel and quality control procedures to produce work of the required quality.

2.2 Welding consumables

2.2.1 Welding consumables used for hull construction are to be approved in accordance with Chapter 11 and are to be suitable for the type of joint and grade of material to be welded.

2.2.2 Steel welding consumable approvals, up to and including Grade Y40 and Y47, are considered acceptable for hull construction in line with Table 11.1.1 in Chapter 11, Ch 12,2.2.2 and the following:

(a) Consumables up to Grade Y are acceptable for welding steels up to 3 strength levels below that for which the approval applies, e.g., a consumable with approval grading 3Y is acceptable for welding EH36, EH32 and EH27S higher tensile ship steels and grade E normal strength ship steel.
(b) Consumables for Grade Y40 are acceptable for welding steels up to two strength levels below that for which the approval applies. Consumables for Grade Y47 are acceptable for welding steels up to one strength level below that for which the approval applies.
(c) Consumables with an approved impact toughness grading are acceptable for welding steels with lower specified impact properties subject to (a) above, e.g. a consumable with approval grading 3Y is acceptable for welding EH, DH and AH materials.
(d) For welding steels of different grades or different strength levels, the welding consumables may be of a type suitable for the lesser grade or strength being connected. The use of a higher grade of welding consumable may be required at discontinuities or other points of stress concentration.

2.2.3 In general, the use of preheating and hydrogen controlled welding consumables for welding of ship steels up to strength grade H40 is to be in accordance with Table 13.2.1. The carbon equivalent is to be calculated from the ladle analysis using the formula given below:

$$\text{Carbon equivalent} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

Preheat and the use of low hydrogen controlled consumables will be required for welding of steel grades higher than Grade H40.

Table 13.2.1 Preheat and consumable requirements for welding of carbon and carbon manganese steels up to strength grade H40

Carbon equivalent C_{eq}	Pre-heat	Hydrogen controlled consumables
C_{eq} equal to or less than 0,41%	Not required	Not required, *see* Note 3
C_{eq} above 0,41 but not exceeding 0,45%	Not required, *see* Notes 1 and 2	Required
C_{eq} greater than 0,45%	Required	Required

NOTES
1. Preheat may need to be applied in order to meet the maximum hardness values specified in Ch 12,2.12.6.
2. Under conditions of high restraint or low ambient temperature preheat may need to be applied.
3. Hydrogen controlled consumables may need to be considered for welding of
   (a) Thicker materials (i.e., > 35 mm).
   (b) Higher strength materials.
   (c) Welds subject to high restraint.

2.2.4 All aluminium alloy welding consumables are to be approved in accordance with Chapter 11 and are suitable for welding the grades of material as shown in Table 13.2.2.

Table 13.2.2 Welding of aluminium alloys – Consumable requirements

Consumable approval grade	Base material alloy grade
RA or WA	5754
RB or WB	5086, 5754
RC or WC	5083, 5086, 5754
RD or WD	6005A, 6061, 6082

2.2.5 All austenitic stainless steel and duplex stainless steel welding consumables are to be approved in accordance with the Chapter 11 and are suitable for welding the grades of material as shown in Table 13.2.3.

2.3 Welding procedure and welder qualifications

2.3.1 Welding procedures and welder qualifications are to be tested and approved in accordance with the requirements of Chapter 12.

2.4 Construction and workmanship

2.4.1 Weld preparations and openings may be formed by thermal cutting, machining or chipping. Chipped surfaces that will not be subsequently covered by weld metal are to be ground smooth.

Table 13.2.3 Welding of austenitic stainless and duplex stainless steels – Consumable requirements

Consumable approval grade	Suitable for welding material alloy grades
Austenitic stainless steels	
321	321
347	347 and 321
Austenitic stainless steel – Low carbon	
304L (*see* Note 3)	304L
304LN (*see* Note 3)	304LN and 304L
316L	316L and 304L
316LN	316LN, 316L, 304LN and 304L
317L	317L, 316LN, 316L, 304LN and 304L
317LN	317LN, 317L, 316LN, 316L, 304LN and 304L
Super austenitic stainless steels, *see* Note 2	
S31254	S31254 and N08904
N08904	N08904
Duplex stainless steels, *see* Note 1	
S31260	S31260 and S31803
S31803	S31803
S32550	S32550
S32750	S32750 and S32550
S32760	S32760, S32550, S31260 and S31803
Stainless steels welded to carbon steels	
SS/CMn	Carbon steel to all steels in Sections 1, 2 and 3
Duplex/CMn	Carbon steel to all duplex stainless steel in Section 4

NOTES
1. The use of a different welding consumable grade from that of the base material may require demonstration of acceptable corrosion properties.
2. May be used for welding low carbon austenitic grades provided measures are taken to prevent solidification cracking from occurring.
3. These are LR Grades and do not correspond to any National or International Standards/Grades.

2.4.2 Prior to welding, the alignment of plates and stiffeners forming part of the hull structure is to be in accordance with the tolerances specified in the relevant part of the Rules.

2.4.3 When welding from one side only, care is to be exercised to ensure the root gap and fit up are in accordance with the approved welding procedure and the root is properly fused.

2.4.4 Where it is proposed to use permanent backing strips, the intended locations and welding procedures are to be submitted for consideration.

2.4.5 Temporary backing strips may be used provided they are in accordance with approved welding procedures and are subsequently removed on completion of welding.

2.4.6 The outer surfaces of completed welds are to blend smoothly with the base materials and provide a smooth transition and gradual change of section.

2.4.7 Weld joints in parts of oil engine structures that are stressed by the main gas or inertia loads are to be designed as continuous full penetration welds. They are to be arranged so that welds do not intersect, and that welding can be effected without difficulty.

2.4.8 When modifications or repairs have been made which result in openings having to be closed by welded inserts, particular care is to be given to the fit of the insert and the welding sequence. The welding is also to be subject to non-destructive examination.

2.4.9 Where welding of aluminium alloy is employed, the following additional requirements are to be complied with so far as they are applicable:

(a) Welding is to be performed by fusion welding using inert gas or tungsten inert gas process or by the friction stir welding process. Where it is proposed to use other welding processes, details are to be submitted for approval.

(b) The weld joint surfaces should be scratch brushed, preferably immediately before welding, in order to remove oxide or adhering films of dirt, filings, etc.

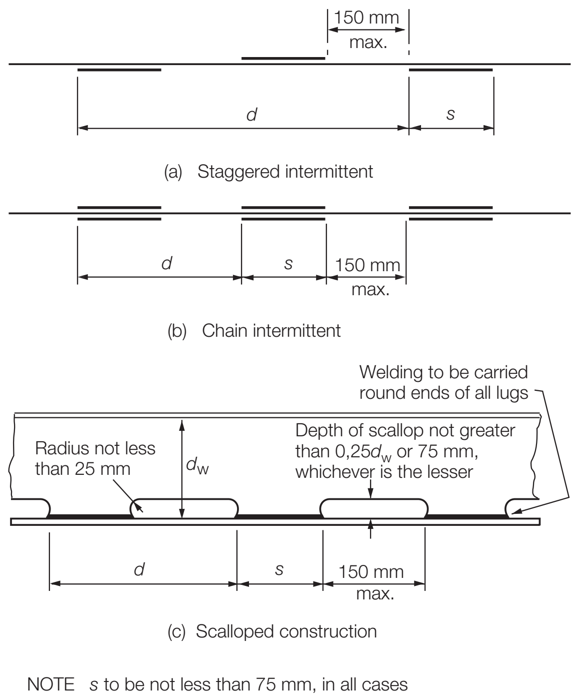


Fig. 13.2.1 Weld types

2.5 Butt welds

2.5.1 Where the ship hull is constructed of plates of different thicknesses, the thicker plates are to be chamfered in accordance with the approved plans. In all cases the chamfer is not to exceed a slope of 1 in 3 so that the plates are of equal thickness at the weld seam. Alternatively, if so desired, the width of the weld may be included as part of the smooth taper to the thicker plate provided the difference in thickness is not greater than 3 mm.

2.5.2 Where stiffening members are attached by continuous fillet welds and cross completely finished butt or seam welds, these are to be made flush in way of the fillet weld. Similarly for butt welds in webs of stiffening members, the butt weld is to be complete and generally made flush with the stiffening member before the fillet weld is made. Where these conditions cannot be complied with, a scallop is to be arranged in the web of the stiffening member, *see* Fig. 13.2.1. Scallops are to be of such a size and in such a position that a satisfactory weld can be made.

2.6 Lap connections

2.6.1 Overlaps are generally not to be used to connect plates which may be subjected to high tensile or compressive loading and alternative arrangements are to be considered. However, where plate overlaps are adopted, the width of the overlap is not to exceed four times, nor be less than three times the thickness of the thinner plate and the joints are to be positioned to allow adequate access for completion of sound welds. The faying surfaces of lap joints are to be in close contact and both edges of the overlap are to have continuous fillet welds.

2.7 Closing plates

2.7.1 For the connection of plating to internal webs, where access for welding is not practicable, the closing plating is to be attached by continuous full penetration welds or by slot fillet welds to face plates fitted to the webs. Slots are to have a minimum length of 90 mm and a minimum width of twice the plating thickness, with well rounded ends. Slots cut in plating are to be smooth and clean and are to be spaced not more than 230 mm apart, centre to centre. Slots are not to be filled with welding.

2.7.2 For the attachment of rudder shell plating to the internal stiffening of the rudder, slots are to have a minimum length of 75 mm and, in general, a minimum width of twice the side plating thickness. The ends of the slots are to be rounded and the space between them is not to exceed 150 mm.

2.8 Stud welding

2.8.1 Where permanent or temporary studs are to be attached by welding to main structural parts in areas subject to high stress, the proposed location of the studs and the welding procedures adopted are to be approved.

2.9 Fillet welds

2.9.1 T-connections are generally to be made by fillet welds on both sides of the abutting plate, the dimensions and spacing of which are shown in Fig. 13.2.1. Where the connection is highly stressed, deep penetration or full penetration welding may be required. Where full penetration welding is required, the abutting plate may be required to be bevelled.

2.9.2 Where an approved deep penetration procedure is used, the fillet leg length calculated may be reduced by 15 per cent provided that the manufacturer is able to meet the following requirements:

(a) Use of a welding consumable approved for deep penetration welding in accordance with Chapter 11 for either the 'p' or 'T' techniques.
(b) Demonstrations by way of production weld testing that the minimum required penetration depths (i.e., throat thicknesses) are maintained. This is to be documented on a monthly basis by the manufacturer and be available to the Surveyor.

2.9.3 The calculated fillet leg length may be reduced by 20 per cent, provided that in addition to the requirements of 2.9.2(a) and (b), the manufacturer is able to consistently meet the following additional requirements:

(a) The documentation required in 2.9.2(b) is to be completed and made available to the Surveyor upon request on a weekly basis.
(b) Suitable process selection confirmed by satisfactory welding procedure tests covering both minimum and maximum root gaps.

2.9.4 Where intermittent welding is used, the welding is to be made continuous in way of brackets, lugs and scallops and at orthogonal connections with other members.

2.10 Post-weld heat treatment

2.10.1 Post-weld stress relief heat treatment is applied to improve the fatigue performance or to improve resistance to brittle fracture and is generally required for carbon and carbon-manganese and low alloy steels under any of the following conditions:

(a) Where the material thickness exceeds 65 mm.
(b) For complicated weld joints where there are high stress concentrations.
(c) Where fatigue loads are considered high.

2.10.2 Post-weld heat treatment is to be applied to the following types of welded construction:

(a) Welding of steel castings where the thickness of the casting at the weld exceeds 30 mm, except where castings are directly welded to the hull structure.
(b) Oil engine bedplates except engine types where the bedplate as a whole is not subjected to direct loading from the cylinder pressure. For these types, only the transverse girder assemblies need to be stress relieved.
(c) Welding of gear wheels.
(d) Welding of gear cases associated with main or auxiliary engines, *see* Part 5 of the Rules for Ships.

2.10.3 Where required, heat treatment is to be performed in accordance with the requirements specified in 4.6 for pressure vessel construction.

2.10.4 Special consideration may be given to omit the required post-weld heat treatment. Evaluation is to be based on critical engineering assessment involving fracture mechanics testing and proposals are to be submitted which include full details of the application, materials, welding procedures, inspection procedures, design stresses, fatigue loads and cycles. Evidence will be required to demonstrate that the inspection techniques and procedures to be employed are able to detect flaws down to the sizes determined from the fracture mechanics (and or fatigue) calculations. Alternative procedures for omission of post-weld heat treatment will be subject to special consideration.

2.11 Tolerances

2.11.1 Tolerances after welding are to be in accordance with the relevant Part of the Rules.

2.11.2 Distortion which has resulted from welding may be corrected by spot heating in accordance with 1.14.

2.12 Non-destructive examination of welds

2.12.1 All finished welds are to be sound and free from cracks and substantially free from lack of fusion, incomplete penetration, porosity and slag. The surfaces of welds are to be reasonably smooth and substantially free from undercut and overlap. Care is to be taken to ensure that the specified dimensions of welds have been achieved and that both excessive reinforcement and under-fill of welds is avoided.

2.12.2 Welds forming part of the hull and superstructure may be coated with a thin layer of protective primer prior to inspection provided it does not interfere with inspection and is removed, if required by the Surveyor, for closer interpretation of possible defective areas.

2.12.3 All welds are to be visually inspected by personnel designated by the builder. Visual inspection of all welds may be supplemented by other non-destructive examination techniques in cases of unclear interpretation, as considered necessary. The acceptance criteria for visual testing are given in Table 13.2.4.

2.12.4 In addition to visual inspection, welded joints are to be examined using any one or a combination of ultrasonic, radiographic, magnetic particle, eddy current, dye penetrant or other acceptable methods appropriate to the configuration of the weld.

Table 13.2.4 Acceptance criteria for visual testing, magnetic particle and liquid penetrant testing

Surface discontinuity	Classification according to ISO 6520-1	Acceptance criteria for visual testing
Crack	100	Not accepted
Lack of fusion	401	Not accepted
Incomplete root penetration in butt joints welded from one side	4021	Not accepted
Surface pore	2017	Single pore diameter $d \le 0{,}25t$, for butt welds, with maximum diameter 3 mm, *see* Note 1 $d \le 0{,}25a$, for fillet welds, with maximum diameter 3 mm, *see* Note 1 2,5d as minimum distance to adjacent pore
Undercut in butt welds	501	Depth ≤ 0,5 mm, whatever the length Depth ≤ 0,8 mm, with a maximum continuous length of 90 mm, *see* Note 2
Undercut in fillet welds	501	Depth ≤ 0,8 mm, whatever the length

NOTES
1. t is the plate thickness of the thinnest plate, and a is the throat of the fillet weld.
2. Adjacent undercuts separated by a distance shorter than the shortest undercut are to be regarded as a single continuous undercut.

2.12.5 The method to be used for the volumetric examinations of welds is the responsibility of the builder. Radiography is generally preferred for the examination of butt welds of 8 mm thickness or less. Ultrasonic testing is acceptable for welds of 8 mm thickness or greater and is to be used for the examination of full penetration tee butt or cruciform welds or joints of similar configuration. Advanced ultrasonic techniques, such as Phased Array Ultrasonic Testing (PAUT), may be used as a volumetric testing method in lieu of radiography or manual ultrasonic testing. If these methods are used, the thickness limitations for manual ultrasonic testing apply.

2.12.6 The acceptance criteria for radiographic testing are given in Table 13.2.5, and those for ultrasonic testing in Table 13.2.6.

2.12.7 Checkpoints examined at the pre-assembly stage are to include ultrasonic testing on examples of the stop/start points of automatic welding and magnetic particle inspection of weld ends.

2.12.8 Checkpoints examined at the assembly stage are generally to be selected from those welds intended to be examined as part of the agreed quality control programme to be applied by the builder. The locations and number of checkpoints are to be approved by the Surveyor.

2.12.9 Where components of the structure are subcontracted for fabrication, the same inspection regime is to be applied as if the item had been constructed within the main contractor's works. In these cases, particular attention is to be given to highly loaded fabrications (such as stabiliser fin boxes) forming an integral part of the hull envelope.

2.12.10 Particular attention is to be paid to highly stressed items. Magnetic particle inspection is to be used at ends of fillet welds, T-joints, joints or crossings in main structural members and at stern frame connections.

2.12.11 Special attention is to be given to the examination of plating in way of lifting eye plate positions to ensure freedom from cracks. This examination is not restricted to the positions where eye plates have been removed, but includes the positions where lifting eye plates are permanent fixtures.

2.12.12 Checkpoints for volumetric examination are to be selected so that a representative sample of welding is examined.

2.12.13 Typical locations for volumetric examination and number of checkpoints to be taken are given in the relevant Sections of the Rules. A list of the proposed items to be examined is to be submitted for approval.

2.12.14 For the hull structure of refrigerated spaces, and of ships designed to operate in low air temperatures, the extent of non-destructive examination will be specially considered. For non-destructive examination of gas ships *see* the *Rules for the carriage for Liquefied Gases*.

2.12.15 For all ship types, the builder is to carry out random non-destructive examination at the request of the Surveyor.

2.12.16 Results of non-destructive examinations made during construction are to be recorded and evaluated by the builder on a continual basis in order that the quality of welding can be monitored. These records are to be available to the Surveyor.

2.12.17 The extent of applied non-destructive examinations is to be increased when warranted by the analysis of previous results.

Table 13.2.5 Acceptance criteria for radiographic testing

Discontinuity	Classification according to ISO 6520-1	Acceptance criteria for radiographic testing, *see* Note 1
Crack	100	Not accepted
Lack of fusion	401	Continuous maximum length $t/2$ or 25 mm, whichever is the less, *see* Note 2 Intermittent cumulative length maximum t or 50 mm, whichever is less, *see* Note 3
Lack of root fusion	4013	Not accepted in butt joints welded from one side
Incomplete root penetration	4021	Not accepted in butt joints welded from one side
		Continuous maximum length $t/2$ or 25 mm, whichever is lesser, *see* Note 2 Intermittent cumulative maximum length t or 50 mm, whichever is less, *see* Note 3
Slag inclusion	301	Continuous maximum length t or 50 mm, whichever is less, *see* Note 2 Intermittent cumulative length maximum $2t$ or 100 mm, whichever is less, *see* Notes 3 and 4
Gas pore	2011	Maximum dimension for a single pore: $d \le 0{,}2t$, max. 4,0 mm *see* Note 5
Uniformly distributed porosity	2012	Maximum dimension of the area of imperfections: For single run welds: ≤ 1,5% For multi-run welds: ≤ 3% *See* Notes 6 and 7
Clustered (localised) porosity	2013	Maximum dimension of the summation of the projected area of the imperfection: ≤ 8% *See* Notes 6 and 7
Elongated cavity	2015	$h \le 0{,}3t$, max. 3,0 mm $l \le t$, max. 50 mm *See* Notes 8 and 9
Wormholes	2016	$h \le 0{,}3t$, max. 3,0 mm $l \le t$, max. 50 mm *See* Notes 8 and 9
Metallic inclusions other than copper	304	$h \le 0{,}3t$, max. 3,0 mm *See* Note 8
Copper inclusions	3042	Not permitted

NOTES
1. t is the thickness of the thinnest plate.
2. Two adjacent individual discontinuities of length l_d1 and l_d2 situated on a line and where the distance l_d between them is shorter than the shortest discontinuity are to be regarded as a continuous discontinuity of length $l_d1 + l_d + l_d2$.
3. Sum of the length of individual continuous discontinuities.
4. Parallel inclusions not separated by more than 3 times the width of the largest inclusion are to be regarded as one continuous discontinuity.
5. d is the diameter of the gas pore.
6. The limits for the maximum single gas pore within this group still apply.
7. Further reference to porosity limits may be obtained in ISO 5817:2007.
8. h is the width of the imperfection.
9. l is the length of the imperfection.

2.13 Weld repairs

2.13.1 The full extent of any weld defect is to be ascertained by applying additional non-destructive examination where required. Unacceptable defects are to be completely removed and, where necessary, re-welded and re-examined in accordance with the requirements of 1.15.

2.13.2 During the assembly of large components, root gaps in excess of those specified in the approved welding procedure may be rectified by welding.

Table 13.2.6 Acceptance criteria for ultrasonic testing

Echo height	Acceptance criteria for ultrasonic testing, *see* Note
Greater than 100% of DAC curve	Maximum length t/2 or 25 mm, whichever is less
Greater than 50% of DAC curve, but less than 100% of DAC curve	Maximum length t or 50 mm, whichever is less
Indications evaluated to be cracks are unacceptable regardless of echo height; Indications evaluated to be lack of penetration or lack of root fusion in joints welded from one side are unacceptable regardless of echo height.	
NOTE Two adjacent individual discontinuities of length L1 and L2 situated on a line and where the distance L between them is shorter than the shortest discontinuity are to be regarded as a continuous discontinuity of length L1 + L + L2.	

2.13.3 Rectification of wide root gaps in butt welds, up to a maximum gap of 16 mm, may be performed provided that the length of these areas is small in relation to the whole weld length. Repairs may be executed by applying weld buttering layers to one edge of the weld joint, followed by machining or grinding to return the root opening to the required dimensions. The weld buttering and filling of the joint are to be in accordance with welding procedures qualified in accordance with Chapter 12.

2.13.4 For sub-assemblies, rectification of wide root gaps may be performed using a backing strip, provided that it is removed on completion of the welding.

2.13.5 Rectification of wide root gaps in fillet welds may be carried out as follows:

(a) where the root gap, g, is in excess of 3 mm, but not greater than 5 mm, the fillet leg length, z, may be increased by g – 2,0 mm;
(b) where the root gap is in excess of 5 mm, the joint detail may be changed into a full penetration weld.

2.13.6 Where repair welds are made using small weld beads, suitable precautions (including preheat) are to be taken to avoid high hardness and possible cold cracking.

2.14 Welding afloat with water backing

2.14.1 Welding afloat with water backing is not recommended due to the additional precautions required during survey and therefore, is generally not permitted. However consideration may be given to welding afloat with water backing after specific LR approval has been obtained by the yard or fabricator prior to such welding being carried out. Such approval will only be given once all of the following conditions are satisfied:

(a) The welding procedure qualification tests are carried out on steel plates with water backing and the water is maintained at the flow rate and minimum water temperature anticipated during fabrication.
(b) The carbon equivalent of the steel plates used in the welding procedure qualification tests are to be greater than 0,41 per cent based on the IIW formula. Where it can be shown that all hull steel plates and new sections will have a carbon equivalent value below this figure, steel plates with the maximum carbon equivalent value may be used for the welding procedure qualification tests.
(c) Welding procedure qualification tests are carried out without preheat.
(d) The thickness of steel plate used in the welding procedure qualification test is the minimum hull plate thickness to be used during fabrication.
(e) The maximum measured hardness on the completed welding procedure qualification assembly is less than or equal to 350 HV10. Following fabrication welding, 10 per cent of welds are to be hardness tested in way of heat-affected zones at weld starts to confirm compliance with the 350 HV10 limit.
(f) The heat input used in the welding qualification test is the minimum permitted heat input during fabrication.
(g) Only low hydrogen welding consumables (H5) are used.
(h) In addition to normal non-destructive testing for welds, 10 per cent of the welds are additionally subject to magnetic particle inspection 48 hours after welding is complete.
(j) The welding procedure qualification tests for the repair of welds carried out afloat with water backing are to be carried out on test pieces that have previously been welded afloat and also meet the requirements above.

2.14.2 For new construction, conversion or permanent repairs, wet underwater welding is not permitted.

■ *Section 3*
Specific requirements for fabricated steel sections

3.1 Scope

3.1.1 Fabricated steel sections are items used in place of rolled sections and as such will not be regarded as sub-assemblies. Products regarded as sub-assemblies are subject to requirements of welded construction specified in Section 2.

3.1.2 The requirements for structural steel sections are based on these being manufactured from flat products by automatic welding and intended for use in the construction of ships and other marine structures.

3.1.3 Fabricated steel sections are to be manufactured in accordance with the requirements of this Section and the general requirements of Section 1.

3.1.4 In all cases, sections are to be manufactured at works, which have been assessed and approved in accordance with *Materials and Qualification Procedures for Ships, Book J, MQPS Procedure 12-1*.

3.2 Dimensions and tolerances

3.2.1 Products are to conform dimensionally to the provisions of an acceptable National or International Standard.

3.2.2 The minimum throat thickness of fillet welds is to be determined from:

Throat thickness = 0,34t but not to be taken as less than 3 mm

where

t = plate thickness of the thinner member to be joined (generally the web).

3.2.3 Where a welding procedure using deep penetration welding is used (*see* Chapter 11, 'p' and 'T' welding techniques) the minimum leg length required will be specially considered provided the requirements of 2.9.2 are complied with.

3.2.4 Unless agreed otherwise, the leg length of the weld is to be not less than 1,4 times the specified throat thickness.

3.3 Identification of products

3.3.1 Every finished item is to be clearly marked by the manufacturer in at least one place with the following particulars:

(a) The manufacturer's name or trade mark.
(b) Identification mark for the grade of steel.
(c) Identification number and/or initials which will enable the full history of the item to be traced.
(d) Where required by the purchaser, the order number or other identification mark.
(e) The letters 'LR'.
(f) The Surveyor's personal stamp.

The above particulars, but excluding the manufacturer's name or trade mark where this is embossed on finished products, are to be encircled with paint or otherwise marked so as to be easily recognisable.

3.3.2 In the event of any material bearing LR's brand failing to comply with the test requirements, the brand is to be removed or unmistakably defaced, *see also* Ch 1,4.7.

3.4 Manufacture and workmanship

3.4.1 For cut edges that are to remain unwelded, it is to be demonstrated that the plate preparation procedures used are able to achieve edges that are free from cracks or other deleterious imperfections.

3.4.2 Where assembly jigs and devices are used to bring the web into contact with the flanges and hold these in place during welding, means are to be provided to ensure that the degree of contact is maintained until welding is complete.

3.4.3 Welding procedures are to be established for the welding of all joints including weld repairs and are to be approved in accordance with Chapter 12. Welders are to be approved in accordance with Chapter 12, and qualification records are to be available to the Surveyor.

3.4.4 The welding consumables used are to be approved in accordance with Chapter 11 and are to be suitable for the type of joint and grade of steel as described in 2.2. For joining steel of different tensile strengths, the consumables are to be suitable for the tensile strength of the component considered in the determination of weld size.

3.4.5 The application of pre-heat and the use of low hydrogen welding consumables are to be in accordance with the requirements of 2.2.

3.4.6 Welding is to be double continuous fillet welding or full penetration welding as specified in the approved plans.

3.4.7 Where deep penetration welding is used, the requirements of 2.9.2 are to be complied with.

3.5 Non-destructive examination

3.5.1 Surface inspection and verification of dimensions are the responsibility of the manufacturer and are to be carried out on all materials prior to despatch. Acceptance by the Surveyor of material later found to be defective does not absolve the manufacturer from this responsibility.

3.5.2 The Surveyor will carry out checks to ensure that the weld size and profile are in accordance with the manufacturing specification and the manufacturer's Quality Control Procedures.

3.5.3 The manufacturer is to examine the welds by magnetic particle or dye penetrant methods. The length examined is to be 200 mm at each end, for each length cut for delivery.

3.5.4 If cracks are revealed, these are to be reported to the Surveyor and the whole of the length is to be examined by magnetic particle or dye penetrant methods. Corrective action in respect of the manufacturing process, and repairs are to be as indicated in the manufacturers' Quality Control Manual.

3.5.5 The weld defect is not to exceed the acceptance levels given in Table 13.2.4.

3.6 Routine weld tests

3.6.1 One production batch test is required for every 500 m of fabricated section manufactured, or fraction thereof. From each batch test, two samples are to be removed, one from near the beginning of the production run and one from near the end. From each of these test samples one macro specimen and one fracture test specimen are to be taken.

3.6.2 The macro specimens are to be prepared and etched to demonstrate freedom from unacceptable defects and that the weld penetration is in accordance with the manufacturing specification. The fracture specimens are to be broken, one for each side of the fillet weld, and the fractured surfaces examined for compliance with the requirements of Table 13.2.5.

3.6.3 Where the welding procedure used has employed the deep penetration technique, the amount of root penetration is to be measured on the macro specimen and is not to be less than that demonstrated during welding procedure approval testing.

3.6.4 For the purposes of this Section, a batch is to consist of products of only one size and grade of material.

3.7 Certification and records

3.7.1 Each test certificate is to include the following particulars:
(a) Purchaser's name and order number.
(b) Where known, the contract number for which the material is intended.
(c) Address to which material is despatched.
(d) Description and dimensions of the product.
(e) Specification or grade of the steel.
(f) Identification number and/or initials.
(g) Cast number and chemical composition of ladle samples of constituent plates.
(h) Mechanical test results of constituent plates.
(j) Condition of supply when other than as-rolled.
(k) Make and brand of welding consumables.

3.7.2 Test certificates or shipping statements may be signed by the Surveyor, provided the documentation requirements of 1.17 are satisfied. The following form of declaration will be accepted if stamped or printed on each test certificate or shipping statement with the name of the works and signed by an authorised representative of the manufacturer:

'We hereby certify that the material has been made by an approved procedure in accordance with the Lloyd's Register's Rules for Materials'.

3.7.3 The manufacturer is to maintain records by which sources of material can be identified together with the results of all inspections and tests.

■ *Section 4*
Specific requirements for fusion welded pressure vessels

4.1 Scope

4.1.1 The requirements of this Section apply to fusion welded pressure vessels and process equipment, heating and steam raising boilers, and steam or gas turbine rotors and cylinders and are in addition to those requirements referred to in Section 1.

4.1.2 The allocation of pressure vessel Class is determined from the design criteria in Pt 5, Ch 10 and 11 of the Rules for Ships. Prior to commencing construction, the design of the vessel is to be approved. Construction requirements for turbine rotors and cylinders are to be in accordance with Class 2/1, unless a higher Class is specified in the approved plans.

4.1.3 Pressure vessels will be accepted only if manufactured by firms equipped and competent to undertake the quality of welding work required for the Class of vessel proposed. The manufacturer's works are to be approved in accordance with the requirements specified in *Materials and Qualification Procedures for Ships, Book A, Procedure MQPS 0-4*.

4.1.4 The term 'fusion weld', for the purpose of these requirements, is applicable to welded joints made by manual, semi-automatic, or automatic electric arc welding processes. Special consideration will be given to the proposed use of other fusion welding processes.

4.2 Cutting and forming of shells and heads

4.2.1 Cut or chipped surfaces which will not be subsequently covered by weld metal are to be ground smooth.

4.2.2 Shell plates and heads are to be formed to the correct contour up to the extreme edge of the plate.

4.2.3 Vessels manufactured from carbon or carbon manganese steel plates (*see* Table 3.4.1 in Chapter 3, grades 360AR to 510FG), which have been hot formed or locally heated for forming, are to be re-heat treated in accordance with the original supplied condition on completion of this operation. Vessels formed from plates supplied in the as-rolled condition are to be heat treated in accordance with the material manufacturer's recommendations.

4.2.4 Subsequent heat treatment will not be required where steels are supplied in the as-rolled, normalised or normalised and controlled rolled condition, or hot forming is carried out entirely at a temperature within the normalising range.

4.2.5 For alloy steel vessels where hot forming is employed (*see* Table 3.4.1 in Chapter 3, 13Cr Mo 45, etc.), the plates are to be heat treated on completion in accordance with the material manufacturer's recommendations.

4.2.6 Where plates are cold formed, subsequent heat treatment is to be performed where the internal radius is less than 10 times the plate thickness. For carbon and carbon-manganese steels this heat treatment may be a stress relief heat treatment.

4.2.7 In all cases where hot forming is employed, and for cold forming to a radius less than 10 times the thickness, the manufacturer is required to demonstrate that the forming process and subsequent heat treatments result in acceptable properties.

4.3 Fitting of shell plates and attachments

4.3.1 The location of welded joints is to be such as to avoid intersecting butt welds in the vessel shell plates. The attachment of nozzles and openings in the vessels are to be arranged to avoid main shell weld seams.

4.3.2 The surfaces of the plates at the longitudinal or circumferential seams are not to be out of alignment with each other, at any point, by more than 10 per cent of the plate thickness. In no case is the misalignment to exceed 3 mm for longitudinal seams, or 4 mm for circumferential seams.

4.3.3 Where a vessel is constructed of plates of different thicknesses (tube plate and wrapper plate), the plates are to be so arranged that their centrelines form a continuous circle.

4.3.4 For longitudinal seams, the thicker plate is to be equally chamfered inside and outside by machining over a circumferential distance not less than twice the difference in thickness, so that the plates are of equal thickness at the longitudinal weld seam. For the circumferential seam, the thickest plate is to be similarly prepared over the same distance longitudinally.

4.3.5 For the circumferential seam, where the difference in the thickness is the same throughout the circumference, the thicker plate is to be reduced in thickness by machining to a taper for a distance not less than four times the offset, so that the two plates are of equal thickness at the weld joint. A parallel portion may be provided between the end of the taper and the weld edge preparation; alternatively, if so desired, the width of the weld may be included as part of the smooth taper to the thicker plate.

4.3.6 All attachments (lugs, brackets, reinforcing plates, etc.) are to conform to the shape of the surface to which they are attached.

4.4 Welding

4.4.1 Welding procedures are to be established for all welds joining pressure containing parts and for welds made directly onto pressure containing parts. Welding procedures are to be based on qualification tests performed in accordance with Chapter 12.

4.4.2 In all cases where tack welds, in the root of the weld seam, are used to retain plates or parts in position prior to welding, they are to be removed in the process of welding the seam.

4.4.3 Steel backing strips may be used for the circumferential seams of Class 2/1, Class 2/2 and Class 3 pressure vessels and are to be the same nominal composition as the plates to be welded.

4.4.4 Fillet welds are to be made to ensure proper fusion and penetration at the root of the fillet. At least two layers of weld metal are to be deposited at each weld affixing branch pipes, flanges and seatings.

4.4.5 The outer surface of completed welds is to be at least flush with the surface of the plates joined, and any weld reinforcement is to provide a smooth transition and gradual change of section with the plate surface.

4.4.6 Where attachment of lugs, brackets, branches, manhole frames, reinforcement plates and other members are to be made to the main pressure shell by welding, this is to be to the same standard as required for the main vessel shell construction.

4.4.7 The main weld seams and all welded attachments made to pressure containing parts are to be completed prior to post-weld heat treatment.

4.4.8 The finish of welds attaching pressure parts and non-pressure parts to the main pressure shell is to be such as to allow satisfactory examination of the welds. In the case of Class 1 and Class 2/1 pressure vessels, these welds are to be ground smooth, if necessary, to provide a suitable finish for examination.

4.5 General requirements for routine weld production tests

4.5.1 Routine weld production tests are specified as a means of monitoring the quality of the welded joints and are required for pressure vessel Classes 1, 2/1 and 2/2.

4.5.2 Routine production test plates are required during the manufacture of vessels and as part of the initial approval test programme for Class 1 vessel manufacturers, refer to MQPS 0-4.

4.5.3 Routine production weld tests are not required for Class 3 pressure vessels unless there are doubts about the weld quality where check tests may be requested by the Surveyor.

4.5.4 Routine production test plates are not required for circumferential seams of cylindrical pressure vessels. Spherical vessels are to have one test plate prepared having a welded joint which is a simulation of the circumferential seams.

4.5.5 Routine production weld tests may be requested by the Surveyor where there is reason to doubt the quality of workmanship.

4.6 Production test plate assembly requirements

4.6.1 Two test plates and one complete test assembly, of sufficient dimensions to provide all the required mechanical test specimens is to be prepared for each vessel and is to be welded as a continuation and simulation of the longitudinal weld joint.

4.6.2 For Class 2/2 vessels, where a large number are made concurrently at the same works using the same welding procedure and the plate thicknesses do not vary by more than 5 mm, one test may be performed for each 37 m of longitudinal plus circumferential weld seam. In these cases the thickness of the test plate is to be equal to the thickest shell plate used in the construction.

4.6.3 Where the vessel size or design results in a small number of longitudinal weld seams, one test assembly may be prepared for testing provided that the welding details are the same for each seam.

4.6.4 Test plate materials are to be the same grade, thickness and supply condition and from the same cast as that of the vessel shell. The test assembly is to be welded at the same time as the vessel weld to which it relates and is to be supported so that distortion during welding is minimised.

4.6.5 As far as practicable, welding is to be performed by different welders where there is a requirement for several routine tests to be welded.

4.6.6 The test assembly may be detached from the vessel weld only after the Surveyor has performed a visual examination and has added his mark or stamp. Straightening of test welds prior to mechanical testing is not permitted.

4.6.7 Where the pressure vessel is required to be subjected to post-weld heat treatment, the test weld is to be heat treated, after welding, in accordance with the same requirements. This may be performed separately from the vessel.

4.7 Inspection and testing

4.7.1 The test weld is to be subjected to the same type of non-destructive examination and acceptance criteria as specified for the weld seam to which the test relates. Non-destructive examination is to be performed prior to removing specimens for mechanical testing, but after any post-weld heat treatment.

4.7.2 The test weld is to be sectioned to remove the number and type of test specimens for mechanical testing as given in 4.8.

4.8 Mechanical requirements

4.8.1 The routine production test assembly is to be machined to provide the following test specimens:

(a) Tensile.
(b) Bend.
(c) Hardness.
(d) Impact (*see* Table 13.4.1).
(e) Macrograph and hardness survey of full weld section.

4.8.2 One set of specimens for mechanical testing are to be removed, as shown in Figs. 13.4.1 or 13.4.2 as appropriate for the Class of approval. Impact tests are to be removed and tested where required by Table 13.4.1.

4.8.3 **Longitudinal tensile test for weld metal**. An all-weld metal longitudinal tensile test is required. For thicknesses in excess of 20 mm, where more than one welding process or type of consumable has been used to complete the joint, additional longitudinal tests are required from the respective area of the weld. This does not apply to the welding process or consumables used solely to deposit the root weld. Specimens are to be tested in accordance with the following requirements:

(a) The diameter and gauge length of the test specimen is to be in accordance with Ch 11,2.1.1.
(b) For carbon and carbon-manganese steels the tensile strength of the weld metal is to be not less than the minimum specified for the plate material and not more than 145 N/mm^2 above this value. The percentage elongation, A, is to be not less than that given by:

A = (980-R)/21,6 but not less than 80 per cent of the minimum elongation specified for the plate

where

R is the tensile strength, in N/mm^2, obtained from the all weld metal tensile tests.

(c) For other materials the tensile strength and percentage elongation is not to be less than that specified for the base materials welded.

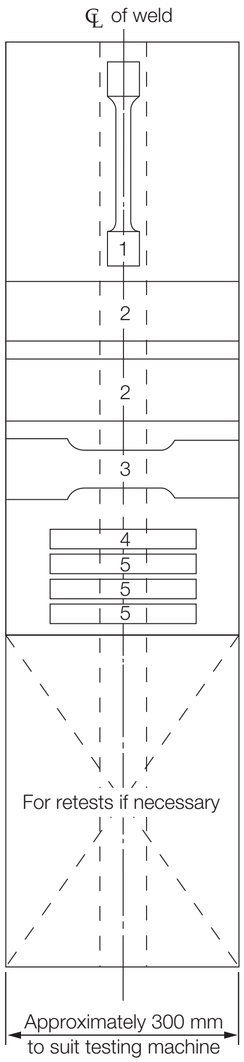
4.8.4 **Transverse tensile test for joint**. Transverse tensile test specimens are to be removed and tested in accordance with the following requirements:

(a) One reduced section tensile test specimen is to be cut transversely to the weld to the dimensions shown in Ch 11,2.1.1 and the weld reinforcement is to be removed.

Table 13.4.1 Impact test requirements

Pressure vessel Class	Minimum design temperature	Plate material thickness t	Impact test temperature
Class 1 *see* Note	–10°C or above	All	5°C below the minimum design temperature or 20°C, whichever is the lower
All Classes	Below –10°C	$t \leq 20$ mm	5°C below the minimum design temperature
		20 mm $< t \leq 40$ mm	10°C below the minimum design temperature
		Over 40 mm	Subject to special consideration

NOTE
Impact testing is not required for Classes 2/1, 2/2 and 3.

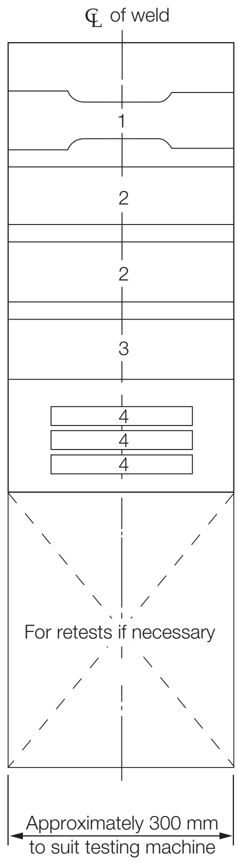


1. All weld metal tensile test specimen.
2. Bend test specimens.
3. Tensile test for joints.
4. Macro-test specimen.
5. Charpy V-notch impact.
   (For all Class 1 pressure vessels and other Classes of pressure vessels where the minimum design temperature is below –10°C).

Fig. 13.4.1
Routine weld test – Test specimens for Class 1 and Class 2/1

(b) In general, where the plate thickness exceeds 30 mm, or where the capacity of the tensile test machine prevents full thickness tests, each tensile test may be made up of several reduced section specimens, provided that the whole thickness of the weld is subjected to testing.

(c) The tensile strength obtained is to be not less than the minimum specified tensile strength for the plate material, and the location of the fracture is to be reported.



1. Tensile test for joints.
2. Bend test specimens.
3. Nicked bend test specimen.
4. Charpy V-notch impact test specimens (if required by Table 13.4.1).

Fig. 13.4.2
Routine weld tests – Test specimens for Class 2/2 and Class 3

4.8.5 **Transverse bend test**. The bend test specimens are to be removed and tested in accordance with the following requirements:

(a) Two bend test specimens of rectangular section are to be cut transversely to the weld, one bent with the outer surface of the weld in tension (face bend), and the other with the inner surface in tension (root bend).

(b) The specimen dimensions are to be in accordance with Chapter 2.

(c) Each specimen is to be mounted on roller supports with the centre of the weld midway between the supports. The former is to have a diameter specified in Ch 12,2.7.6 depending on the material being welded.

(d) After bending through an angle of at least 180° there is to be no crack or defect exceeding 1,5 mm measured across the specimen or 3 mm measured along the specimen. Premature failure at the edges of the specimen is not to be cause for rejection, unless this is associated with a weld defect.

4.8.6 **Macro-specimen and hardness survey**. A macro examination specimen is to be removed from the test assembly near the end where welding started. The specimen is to include the complete cross-section of the weld and the heat affected zone. The specimen is to be prepared and examined in accordance with the following requirements:

(a) The cross-section of the specimen is to be ground, polished and etched to clearly reveal the weld runs, and the heat affected zones.
(b) The specimen is to show an even weld profile that blends smoothly with the base material and have satisfactory penetration and fusion, and an absence of significant inclusions or other defects.
(c) Where there is doubt in the condition of the weld as shown by macro-etching, the area concerned is to be microscopically examined.
(d) For carbon, carbon manganese and low alloy steels, a Vickers hardness survey is to be performed on the macro-specimen using either a 5 kg or 10 kg load. Testing is to include the base material, the weld and the heat affected zone. Hardness scans on the cross-section are to be performed as specified in Fig. 12.2.9 in Chapter 12. The maximum recorded hardness is to not exceed 350 Hv.

4.8.7 **Charpy V-notch impact test**. Charpy V notch impact test specimens are to be prepared and tested as required by Table 13.4.1 and in accordance with the following requirements:

(a) The dimensions and tolerances of the specimens are to be in accordance with Chapter 2.
(b) Charpy V-notch impact specimens and are to be removed with the notch perpendicular to the plate surface.
(c) Specimens are to be removed for testing from the weld centreline and the heat affected zone (fusion line and fusion line + 2 mm locations) detailed in Fig. 12.2.6 or Fig. 12.2.7 in Chapter 12, as appropriate. Heat affected zone impact tests may be omitted where the minimum design temperature is above +20°C.
(d) For thicknesses in excess of 20 mm, where more than one welding process or type of consumable has been used to complete the joint, impact tests are required from the respective areas of the weld. This does not apply to the welding process or consumables used solely to deposit the root weld.
(e) The average energy of a set of three specimens is not to be less than 27 J or the minimum specified for the base material, whichever is the higher. The minimum energy for each individual specimen is to meet the requirements of Ch 1,4.5.2.

4.8.8 **Nick break bend tests**. A nick bend or fracture test specimen is to be a minimum of 100 mm long measured along the weld direction and is to be tested in accordance with and meet the requirements of the following:

(a) The specimen is to have a slot cut into each side along the centreline of the weld and perpendicular to the plate surface.
(b) The specimen is to be bent along the weld centreline until fracture occurs and the fracture faces are to be examined for defects. The weld is to be sound, with no evidence of cracking or lack of fusion or penetration and be substantially free from slag inclusions and porosity.

4.9 Failure to meet requirements

4.9.1 Where any test specimen fails to meet the requirements, additional specimens may be removed and re-tested in accordance with Ch 2,1.4.

4.9.2 Where a routine weld test fails to meet requirements, the welds to which it relates will be considered as not having met the requirements. The reason for the failure is to be established, and the manufacturer is to take such steps as necessary to either

(a) Remove the affected welds and have them re-welded, or
(b) Demonstrate that the affected production welds have acceptable properties.

4.10 Post-weld heat treatment

4.10.1 Fusion welded pressure vessels, where indicated in Table 13.4.2, are to be heat treated on completion of the welding of the seams and of all attachments to the shell and ends, and before the hydraulic test is carried out.

4.10.2 Tubes which have been expanded into headers or drums may be seal welded without further post-weld heat treatment.

4.10.3 Steam and gas turbine cylinders and rotors are to be subjected to post-weld heat treatment irrespective of thickness.

4.10.4 Where the weld attaches parts of different thicknesses, the thickness to be used when applying the requirements for post-weld heat treatment is to be either the thinner of the two plates for butt welded connections, or the thickness of the shell for welds to flanges, tubeplates and similar connections.

4.10.5 Care is to be exercised to provide drilled holes in double reinforcing plates and other closed spaces prior to heat treatment.

4.11 Basic requirements for post-weld heat treatment of fusion welded pressure vessels

4.11.1 Recommended soaking temperatures and soak durations for post-weld heat treatment are given in Table 13.4.3 for different materials. Where other materials are used for pressure vessel construction, full details of the proposed heat treatment are to be submitted for consideration.

4.11.2 Where pressure vessels are of dimensions that the whole length cannot be accommodated in the furnace at one time, the pressure vessels may be heated in sections, provided that sufficient overlap is allowed to ensure the heat treatment of the entire length of the longitudinal seam.

4.11.3 Where materials other than those detailed in Table 13.4.3 are used or where it is proposed to adopt special methods of heat treatment, full particulars are to be submitted for consideration. In such cases, it may be necessary to carry out tests to show the effect of the proposed heat treatment.

Table 13.4.2 Post-weld heat treatment requirements

Type of steel	Plate thickness above which post-weld heat treatment (PWHT) is required	
	Steam raising plant	Other pressure vessels
Carbon and carbon/manganese steels without low temperature impact values	20 mm	30 mm
Carbon and carbon/manganese steels with low temperature impact values	20 mm	40 mm
1Cr ½Mo	All thicknesses	All thicknesses
2¼Cr 1Mo	All thicknesses	All thicknesses
½Cr ½Mo ¼V	All thicknesses	All thicknesses
Other alloy steels	Subject to special consideration	

Table 13.4.3 Post-weld soak temperatures and times

Material type	Soak temperature (°C)	Soak period
Carbon and carbon/manganese grades	580–620°	1 hour per 25 mm of thickness, minimum of 1 hour
1Cr ½Mo	620–660°	1 hour per 25 mm of thickness, minimum of 1 hour
2¼Cr 1Mo	650–690°	1 hour per 25 mm of thickness, minimum of 1 hour
½Cr ½Mo ¼V	670–720°	1 hour per 25 mm of thickness, minimum of 1 hour
NOTE For materials supplied in the tempered condition, the post-weld heat treatment temperature is to be lower than the material tempering temperature.		

4.12 Non-Destructive Examination of welds

4.12.1 Non-Destructive Examinations (NDE) of pressure vessel welds are to be carried out in accordance with a nationally recognised code or standard.

4.12.2 NDE is not to be applied until an interval of at least 48 hours has elapsed since the completion of welding.

4.12.3 NDE Personnel are to be qualified to an appropriate level of a nationally recognised certification scheme.

4.12.4 Qualification schemes are to include assessments of practical ability for Levels I and II individuals. These examinations are to be made on representative test pieces containing relevant defects.

4.13 Extent of NDE for Class 1 pressure vessels

4.13.1 All butt welded seams in drums, shells, headers and test plates, together with tubes or nozzles with outside diameter greater than 170 mm, are subject to 100 per cent volumetric and surface crack detection inspections.

4.13.2 For circumferential butt welds in extruded connections, tubes, headers and other tubular parts with an outside diameter of 170 mm or less, at least 10 per cent of the total number of welds is to be subjected to volumetric examination and surface crack detection inspections.

4.13.3 Full penetration tube sheet to shell welds are to be subjected to 10 per cent volumetric examination and 10 per cent surface inspection, prior to the installation of the tubes.

4.13.4 In addition to the acceptance limits stated in Tables 13.2.4 to 13.2.6, no cracks, lack of fusion, or lack of penetration is permitted.

4.13.5 When an unacceptable indication is detected, the full length of the weld is to be subjected to 100 per cent examination by the same method, testing conditions and acceptance criteria.

4.14 Extent of NDE for Class 2/1 pressure vessels

4.14.1 For Class 2/1 pressure vessels, volumetric and surface crack detection inspections are to be applied at selected regions of each main seam. At least 10 per cent of each main seam is to be examined together with the full length of each welded test plate. When an unacceptable indication is detected, at least two additional check points in the seam are to be selected by the surveyor for examination using the same inspection method. Where further unacceptable defects are found either:

(a) the whole length of weld represented is to be cut out and re-welded and re-examined as if it was a new weld with the test plates being similarly treated, or
(b) the whole length of the weld represented is to be re-examined using the same inspection methods.

4.14.2 Butt welds in furnaces, combustion chambers and other pressure parts for fired pressure vessels under external pressure, are to be subject to spot volumetric examination. The minimum length for each check point is to be 300 mm.

4.14.3 The extent of NDE for turbine cylinders and rotors is to be agreed with the Surveyor.

4.14.4 The requirements of 4.13.3, 4.13.4 and 4.13.5 apply to Class 2/1 pressure vessels.

4.15 NDE Method

4.15.1 Volumetric examinations may be made by radiography. For welds of nominal thickness greater than or equal to 8 mm, the examinations may be by ultrasonic testing. The preferred method for surface crack detection in ferrous metals is magnetic particle inspection. The preferred method for non-magnetic materials is liquid penetrant inspection.

4.16 Evaluation and reports

4.16.1 The manufacturer is to be responsible for the review, interpretation, evaluation and acceptance of the results of NDE. Reports stating compliance, or non-compliance, with the criteria established in the inspection procedure are to be issued. Reports are to comply, as a minimum, with the requirements of Ch 1,5.

4.17 Repair to welds

4.17.1 Where non-destructive examinations reveal unacceptable defects in the welded seams, they are to be repaired in accordance with 1.15 and are to be shown by further non-destructive examinations to have been eliminated.

4.17.2 In the case where spot radiography has revealed unacceptable defects, the requirements of 4.14.1 apply.

4.17.3 Where post-weld heat treatment is required in accordance with 4.10, weld repairs to the vessel or cylindrical shell or parts attaching to the shell are to be subjected to a subsequent heat treatment in accordance with 4.10.

4.17.4 In the event of unsuccessful weld repair of a defect, only one more repair attempt may be made of the same defect. Any subsequent repairs may require the re-repair excavation to be enlarged to remove the original repair heat affected zone.

■ *Section 5* Specific requirements for pressure pipework

5.1 Scope

5.1.1 Fabrication of pipework is to be carried out in accordance with the requirements of this Section and the general requirements given in Section 1, unless more stringent requirements have been specified.

5.1.2 Piping systems are to be constructed in accordance with the approved plans and specifications.

5.1.3 Fabricated pipework will be accepted only if manufactured by firms that have demonstrated that they have the facilities and equipment and are competent to undertake the quality of welding required for the Class of pipework proposed.

5.2 Manufacture and workmanship

5.2.1 Pipe welding may be performed using manual, semi-automatic or fully automatic electric arc processes. The use of oxy-acetylene welding will be limited to Class 3 pipework in carbon steel or carbon/manganese material that is not for carrying flammable fluids and limited to butt joints in pipes not exceeding 100 mm diameter or 9,5 mm thickness.

5.2.2 Welding of pipework, including attachment welds directly to pressure retaining parts is to be performed in accordance with approved welding procedures that have been qualified in accordance with Chapter 12.

5.2.3 Where the work involves a significant number of branch connections, tests will be required to demonstrate that the type of joint(s) and welding techniques employed are capable of achieving the required quality.

5.2.4 Where pressure pipework is assembled and butt welded insitu, the piping is to be arranged well clear of adjacent structures to allow sufficient access for preheating, welding, heat-treatment and non-destructive examination of the joints.

5.2.5 Alignment of pipe butt welds is to be in accordance with Table 13.5.1 unless more stringent requirements have been agreed. Where fusible inserts are used, the alignment is to be within 0,5 mm in all cases.

5.2.6 The number of welds is to be kept to a minimum. The minimum separation between welds, measured toe-to-toe, is to be not be less than 75 mm. Where it is not possible to achieve this, adjacent welds are to be subjected to surface crack detection NDE.

5.2.7 Welding consumables and fusible root inserts, where used, are to be suitable for the materials being joined.

Table 13.5.1 Pipe butt weld alignment tolerances

Pipe size	Maximum permitted misalignment
D < 150 mm and $t \le$ 6 mm	1,0 mm or 25% of t, whichever is the lesser
D < 300 mm and $t \le$ 9,5 mm	1,5 mm or 25% of t, whichever is the lesser
$D \ge$ 300 and t > 9,5 mm	2,0 mm or 25% of t, whichever is the lesser
where D = pipe internal diameter t = pipe wall thickness	

5.2.8 Acceptable methods of flange attachment are to be used, *see* Fig. 12.2.2 in Pt 5, Ch 12 of the Rules for Ships. Where backing rings are used with flange type (a) they are to fit closely to the bore of the pipe and be removed after welding. The rings are to be made of the same material as the pipes. The use of flange types (b) and (c) with alloy steel pipes is limited to pipes up to and including 168,3 mm outside diameter.

5.2.9 Where socket welded fittings are employed, the diametrical clearance between the outside diameter of the pipe and the base of the fitting is not to exceed 0,8 mm, and a gap of approximately 1,5 mm is to be provided between the end of the pipe and the internal step at the bottom of the socket.

5.2.10 For welding of carbon, carbon/manganese and low alloy steels, the preheat to be applied will be dependent on the material grade, thickness and hydrogen grading of the welding consumable in accordance with Table 13.5.2, unless welding procedure testing indicates that a higher level is required.

5.2.11 Welding without filler metal is generally not permitted for welding of duplex stainless steel materials.

5.2.12 All welds in high pressure, high temperature pipelines are to have a smooth surface finish and even contour; and where necessary, made smooth by grinding.

5.2.13 Check tests of the quality of the welding are to be carried out periodically.

5.3 Heat treatment after bending of pipes

5.3.1 After forming or bending of pipes, the heat treatments specified in this Section are to be applied unless the pipe material manufacturer specifies or recommends other requirements.

5.3.2 Generally, hot forming is to be carried out within the normalising temperature range. When carried out within this temperature range, no subsequent heat treatment is required for carbon and carbon/manganese steels. For alloy steels, 1Cr 1/2Mo, 2 1/4Cr 1Mo and 1/2Cr 1/2Mo 1/4V, a subsequent tempering heat treatment in accordance with the temperatures and times specified in Table 13.5.3 is required, irrespective of material thickness.

5.3.3 When hot forming is performed outside the normalising temperature range, a subsequent heat treatment in accordance with Table 13.5.3 is required.

5.3.4 After cold forming to a radius (measured at the centreline of the pipe) of less than four times the outside diameter, heat treatment in accordance with Table 13.5.3 is required.

5.3.5 Heat treatment should be carried out in accordance with 1.16.

Table 13.5.2 Welding preheat levels for pipework

Material Grade	Thickness, t (mm) *see* Note 4	Minimum preheat temperature (°C) *See* Note 1	
		Non-low H_2	Low H_2 *see* Note 2
Carbon and carbon/manganese grades: 320 and 360	$t \le 15$ $t \ge 15$	50 100	10 50
Carbon and carbon/manganese grades: 410, 460 and 490	$t \le 15$ $t \ge 15$	75 150	20 100
1Cr ½Mo	$t < 13$ $t \ge 13$	*See* Note 3	100 150
2¼Cr 1Mo	$t < 13$ $t \ge 13$	*See* Note 3	150 200
½Cr ½Mo ¼V	$t < 13$ $t \ge 13$	*See* Note 3	150 200

NOTES
1. Where the ambient temperature is 0°C or below, pre-warming of the weld joint is required in all cases.
2. Low hydrogen process or consumables are those that have been tested and have achieved a grading of H15 or better (*see* Chapter 11).
3. Low hydrogen welding process is required for these materials.
4. t = the thickness of the thinner member for butt welds, and the thicker member for fillet and branch welds.

Table 13.5.3 Heat treatment after bending of pipes

Type of steel	Heat treatment required
Carbon and carbon/manganese: Grades 320, 360, 410, 460 and 490	Normalise at 880 to 940°C
1Cr ½Mo	Normalise at 900 to 940°C, followed by tempering at 640 to 720°C
2¼Cr 1Mo	Normalise at 900 to 960°C, followed by tempering at 650 to 780°C
½Cr ½Mo ¼V	Normalise at 930 to 980°C, followed by tempering at 670 to 720°C
Other alloy steels	Subject to special consideration

5.3.6 Bending procedures and subsequent heat treatment for other alloy steels will be subject to special consideration.

5.4 Post-weld heat treatment

5.4.1 Post-weld heat treatment is to be carried out in accordance with the general requirements specified in 1.16 and 4.10.

5.4.2 The thickness limits, the recommended soaking temperatures and periods, for application of post-weld heat treatment are given in Table 13.5.4.

5.4.3 Where the use of oxy-acetylene welding is proposed, due consideration is to be given to the need for normalising and tempering after such welding.

5.5 Non-destructive examination

5.5.1 Non-destructive examination of pipe welds is to be carried out in accordance with the general requirements of 1.11 and the following.

5.5.2 Butt welds in Class 1 pipes with an outside diameter greater or equal to 75 mm are to be subject to 100 per cent volumetric and visual inspections. Consideration is to be given to the extent and method of testing applied to butt welds in Class 1 pipes with an outside diameter less than 75 mm.

5.5.3 Butt welds in Class II pipes are to be subjected to at least 10 per cent random volumetric inspections when the outside diameter is greater than 100 mm.

5.5.4 NDE for Class II pipes with a diameter less than 100 mm is to be at the discretion of the Surveyor.

5.5.5 Non-destructive examination procedures, methods and the evaluation of reports are to be in accordance with 4.15 and 4.16.

5.5.6 Fillet welds on flange pipe connections of Class I pipes are to be examined by surface crack detection methods.

5.6 Repairs to pipe welds

5.6.1 Where non-destructive examinations reveal unacceptable defects in a weld, the defects are to be removed and repaired in accordance with 1.15. Completed repairs are to be shown by further non-destructive examination to have eliminated the defects.

5.6.2 For pipes with diameter less than 88 mm and where unacceptable defects have been found during non-destructive examination, consideration is to be given to cutting the weld out completely, re-making the weld preparation and re-welding as a new joint (because of the difficulty of making small repairs).

Table 13.5.4 Post-weld heat treatment requirements for pipework

Material Grade	Thickness for which post-weld heat treatment is required	Soak temperature (°C) *see* Note 2	Soak period
Carbon and carbon/manganese grades: 320, 360, 410, 460, 490	Over 30 mm	580–620°C	1 hour per 25 mm of thickness, minimum of 1 hour
1Cr ½Mo	Over 8 mm	620–660°C	1 hour per 25 mm of thickness, minimum of 1 hour
2¼Cr 1Mo	All	650–690°C	1 hour per 25 mm of thickness, minimum of 1 hour
½Cr ½Mo ¼V	All, *see* Note 1	670–720°C	1 hour per 25 mm of thickness, minimum of 1 hour

NOTES
1. Heat treatment may be omitted for thicknesses up to 8 mm and diameters not exceeding 100 mm provided welding procedure tests have demonstrated acceptable properties in the as welded condition.
2. For materials supplied in the tempered condition, the post-weld heat treatment temperature is to be at least 20°C less than the material tempering temperature.

5.6.3 Where repeated weld repairs have to be made to a weld, only two such attempts are to be permitted, thereafter the weld is to be cut apart and removed, and re-welded as a new joint.

5.6.4 Where pipework requires post-weld heat treatment weld, repairs to the pressure retaining parts are to be subjected to a subsequent heat treatment. Similarly, where welding is conducted after pressure testing, a further pressure test is to be required unless specific exemption has been agreed.

■ *Section 6* Repair of existing ships by welding

6.1 Scope

6.1.1 This Section specifies requirements for repairs made by welding after introduction into service. This Section includes defects to hull structures, machinery, equipment and components. It also includes replacement of structure due to damage or corrosion. These requirements are in addition to those specified in the preceding Sections of this Chapter.

6.1.2 These requirements apply unless the original builder or manufacturer has specified alternative requirements.

6.2 Materials used for repairs

6.2.1 Permanent materials used in the repair are to be in accordance with 1.3.

6.2.2 Prior to commencing any welding, the material grades present in the original structure in way of the repair are to be determined. Where the materials cannot be identified from the ship records, test samples may be removed for chemical analysis and mechanical testing in order to determine the material grades.

6.2.3 Temporary materials that are to be welded to the main structure to assist in executing the repairs, but removed on completion, are to be of weldable quality.

6.3 Workmanship

6.3.1 A repair method is to be established by the shipyard or repair yard and is to be agreed by the Surveyor prior to commencing any repair work.

6.3.2 The removal of crack-like defects is to be confirmed by visual examination and surface crack detection NDE. This may be augmented by ultrasonic examination where several defects are reported at different depths at the same location.

6.3.3 The weld joint or groove shape used for the repair is to have a profile suitable for welding.

6.3.4 The weld area is to be carefully cleaned, in particular, where the material surface has been painted or has been subjected to an oily or greasy environment.

6.4 Non-destructive examination

6.4.1 On completion of welding and any post-weld heat treatment, repair welds are to be subjected to the type and extent of NDE and assessed in accordance with the acceptance criteria specified for the original construction.

6.4.2 Where the original construction specification did not specify NDE, the completed welds are to be, as a minimum, subject to visual examination. Consideration of other NDE techniques is to take due cognisance of the location or the repair within the vessel.

6.4.3 Where spot NDE is applied and defects are found, the extent of NDE is to be increased to include an equal amount of weld length. Where this reveals unacceptable defects, either the whole weld will be rejected or the extent of inspection increased to 100 per cent examination.

6.4.4 The acceptance criteria to be applied are to generally be in accordance with the original build specification. Where conflict of requirements exist, the NDE acceptance limits for welding procedure tests specified in Ch 12,2.5.5 may be used as a minimum requirement.

6.5 Repairs to welds defects

6.5.1 Where NDE reveals unacceptable defects, these are to be repaired in accordance with 1.15.

■ *Section 7* Austenitic and duplex stainless steel – Specific requirements

7.1 Scope

7.1.1 This Section specifies requirements for the fabrication and welding of austenitic and duplex stainless steels, and is in addition to those detailed above.

7.1.2 Fabrication and welding of these materials is to be in designated areas which are separated from those used for other materials, such as carbon steels and copper alloys. Where work is performed in the same workshop as other materials, adequate barriers or screening are to be provided to prevent cross-contamination of different material types.

7.1.3 All tools and equipment used are to be suitable for use on stainless steel materials. The use of tools or equipment made of carbon steel materials is to be avoided. It is permissible to use carbon steel tools provided that the surfaces that come into contact with the austenitic and duplex stainless materials are protected with an austenitic or nickel base alloy.

7.2 Design

7.2.1 Care is to be exercised in the weld design to prevent crevice corrosion from occurring, particularly where austenitic materials are used. In this respect fillet welds and partial penetration welds are to be continuous and welded on both sides of the joint.

7.3 Forming and bending

7.3.1 Materials that are cold formed, such that the total strain exceeds 15 per cent (i.e., where the formed diameter to thickness ratio is less than 6:1) are to be subjected to a subsequent softening heat treatment in accordance with the material manufacturers recommendations, unless it is demonstrated by testing that the material properties are acceptable in the 'as formed' condition.

7.3.2 Materials may be hot formed provided that a subsequent softening heat treatment is carried out. The forming process and the subsequent heat treatment are to be in accordance with the material manufacturer's recommendations.

7.4 Fabrication and welding

7.4.1 Welding may be performed using shielded manual arc welding (SMAW), gas tungsten arc welding (GTAW), MIG/MAG welding (GMAW), flux cored arc welding (FCAW), plasma arc welding (PAW) and submerged arc welding (SAW). The use of other welding processes will be subject to special consideration and will require submission of the process details, consumables and the weld properties achieved.

7.4.2 Misalignment may be corrected by the application of steady even force (e.g., using hydraulic or screw-type clamps). Hammering or heating is not permitted.

7.4.3 For full penetration welds, a backing or shielding gas is to be provided to prevent oxidation of the root weld. The backing gas is to be maintained until completion of, at least, the root and first fill layer. The backing gas may be omitted where the weld is back gouged or ground to remove the root weld.

7.4.4 Shielding and backing gases are to be an inert type of high purity and oxygen free.

7.4.5 For welding of Duplex stainless, the use of backing gases that contain up to 2 per cent nitrogen is permitted.

7.4.6 Welding of duplex stainless steels without filler metal is generally not permitted.

7.4.7 Degreasing agents, acid solutions, washing water etc. used for cleaning and any marking crayons and paints used are to be free of chlorides.

7.5 Repairs

7.5.1 Correction of distortion by the application of heat is not permitted.

■ *Section 8* Specific requirements for welded aluminium

8.1 Scope

8.1.1 This Section specifies requirements for the fabrication and welding of aluminium alloys, and is in addition to those detailed in this Chapter.

8.1.2 Fabrication and welding of these materials is to be in designated areas which are separated from those used for other materials, such as carbon steels, stainless steels and copper alloys. Where work is performed in the same workshop as other materials, adequate barriers or screening are to be provided to prevent cross-contamination of different material types.

8.1.3 All tools and equipment used are to be suitable for use on aluminium alloy materials. The use of tools made of carbon steel materials is to be avoided where possible.

8.2 Forming and bending

8.2.1 Aluminium alloys are to be subject to cold forming and cold bending only.

8.3 Fabrication and welding

8.3.1 Welding may be performed using gas tungsten arc welding (GTAW) or metal inert gas welding (GMAW), MIG/MAG welding (GMAW), or variants thereof. The use of other welding processes such as friction stir welding (FSW) will be subject to special consideration and will require submission of the process details, consumables and the weld properties achieved.

8.3.2 A comparison of the mechanical properties for selected welded and unwelded alloys is given in Table 13.8.1.

8.3.3 Misalignment may be corrected by the application of steady even force (e.g., using hydraulic or screw-type clamps). Hammering or heating is not permitted.

8.3.4 Correction of distortion by the application of heat is not permitted.

Table 13.8.1 Minimum mechanical properties for aluminium alloys

Alloy	Condition		0,2% proof stress, N/mm^2		Ultimate tensile strength, N/mm^2	
			Unwelded	Welded (*see* Note 4)	Unwelded	Welded (*see* Note 4)
5083	O/H111		125	125	275	275
5083	H112		125	125	275	275
5083	H116/H321		215	125	305	275
5383	O/H111		145	145	290	290
5383	H116/H321		220	145	305	290
5086	O/H111		100	95	240	240
5086	H112		125 (*see* Note 2)	95	250 (*see* Note 2)	240
5086	H116/H321		195	95	275	240
5059	O/H111		160	160	330	330
5059	H116/H321		260	160	360	300
5456	O		125	125	285	285
5456	H116		200 (*see* Note 5)	125	290 (*see* Note 5)	285
5456	H321		215 (*see* Note 5)	125	305 (*see* Note 5)	285
5754	O/H111		80	80	190	190
6005A (see Note 1)	T5/T6	Extruded: Open Profile Extruded: Closed Profile	215 215	100 100	260 250	160 160
6061 (see Note 1)	T5/T6	Rolled Extruded: Open Profile Extruded: Closed Profile	240 240 205	125 125 125	290 260 245	160 160 160
6082	T5/T6	Rolled Extruded: Open Profile Extruded: Closed Profile	240 260 240	125 125 125	280 310 290	190 190 190

NOTES
1. These alloys are not normally acceptable for application in direct contact with sea-water.
2. See also Table 8.1.3 or Table 8.1.4 in Chapter 8.
3. The mechanical properties to be used to determine scantlings in other types and grades of aluminium alloy manufactured to National or proprietary standards and specifications are to be individually agreed with LR, *see also* Ch 8,1.1.5.
4. Where detail structural analysis is carried out, 'unwelded' stress values may be used away from heat affected zones and weld lines, *see also* Pt 3, Ch 2, 1.1.3 of the Rules for Ships.
5. For thickness less than 12,5 mm, the minimum unwelded 0,2% proof stress is to be taken as 230 N/mm^2 and the minimum tensile strength is to be taken as 315 N/mm^2.

8.4 Non-destructive examination

8.4.1 The requirements of Ch 13,1.11 and Ch 13,2.12 apply; however, acceptance criteria applicable to aluminium are to be in accordance with Table 13.8.2 and Table 13.8.3.

8.4.2 Alternative NDE acceptance criteria will be subject to special consideration provided that they are equivalent to these requirements.

Table 13.8.2 Acceptance criteria for surface imperfections of aluminium

Surface discontinuity	Classification according to ISO 6520-1	Acceptance criteria
Crack	100	Not permitted
Lack of fusion	401	Not permitted
Incomplete root penetration in butt joints welded from one side	4021	Not permitted
Surface pore	2017	$d \leq 0{,}3s$ or $0{,}3a$ or 1,5 mm (whichever is the lesser)
Linear porosity (*see* Note 1)	2014	Not permitted
Uniformly distributed porosity (*see* Note 2)	2012	≤ 1% of area
Clustered porosity	2013	Not permitted
Continuous undercut	5011	$h \leq 0{,}1t$ or 0,5 mm (whichever is the lesser)
Intermittent undercut	5012	$h \leq 0{,}1t$ or 1,0 mm (whichever is the lesser)
Excess weld metal (*see* Note 3)	502	$h \leq 1{,}5$ mm + $0{,}15b$ or 8 mm (whichever is the lesser)
Excess penetration	504	$h \leq 4$ mm
Root concavity (*see* Note 3)	515	$h \leq 0{,}1t$ or 1 mm (whichever is the lesser)
Linear misalignment (*see* Notes 4 and 5)	507	$h \leq 0{,}1t$ or 1,0 mm (whichever is the lesser)
Angular misalignment	508	(*see* Note 6)

Symbols

a = nominal throat thickness of a fillet weld
b = width of weld reinforcement
d = diameter of a gas pore
h = height or width of an imperfection
s = nominal butt weld thickness
t = wall or plate thickness (nominal size)

NOTES
1. For these acceptance criteria, linear porosity is to be considered as three aligned gas pores in a length of 25 mm.
2. To be in accordance with EN ISO 10042.
3. A smooth transition is required.
4. Linear misalignment is to be a maximum of 0,5 mm in highly stressed areas. For other areas, the linear misalignment is to be a maximum of 1,0 mm locally, where the sum of the length of imperfection is not more than 10% of the weld length.
5. The limits for linear misalignment relate to deviations from the correct position. Unless otherwise specified, the correct position is that when the centrelines coincide.
6. Angular misalignment shall be mutually agreed between the designer and the fabricator.

Table 13.8.3 Acceptance criteria for internal imperfections of aluminium

Internal discontinuity	Classification according to ISO 6520-1	Acceptance criteria (*see* Note 1)
Crack	100	Not permitted
Lack of fusion	401	Not permitted
Incomplete penetration	402	Not permitted
Single gas pore	2017	$d \le 0{,}3s$ or $0{,}3a$ or 5 mm (whichever is the lesser)
Linear porosity	2014	Assess as lack of fusion
Uniformly distributed porosity (*see* Note 1)	2012	$0{,}5 < t < 3$ mm ≤ 2% of area $3 < t < 12$ mm ≤ 4% of area $12 < t < 30$ mm ≤ 6% of area $t > 30$ mm ≤ 8% of area
Clustered porosity (*see* Note 1)	2013	$dA \le 20$ mm or wp (whichever is the lesser)
Elongated cavity Wormhole	2015 2016	$l \le 0{,}3s$ or $0{,}3a$ or 4 mm (whichever is the lesser)
Oxide inclusion (*see* Note 2)	303	$l \le 0{,}5s$ or $0{,}5a$ or 5 mm (whichever is the lesser)
Tungsten inclusion	3041	$l \le 0{,}3s$ or $0{,}3a$ or 4 mm (whichever is the lesser)
Copper inclusion	3042	Not permitted
Multiple imperfections in any cross-section	—	The sum of the acceptable individual imperfections in any cross-section is not to exceed $0{,}3t$ or $0{,}3a$ (whichever is the lesser)

Symbols

a = nominal throat thickness of a fillet weld
b = width of weld reinforcement
d = diameter of a gas pore
h = height or width of an imperfection
s = nominal butt weld thickness
t = wall or plate thickness (nominal size)
wp = width of weld or width or height of cross-sectional area
dA = diameter of area surrounding gas pores
l = length of imperfection in longitudinal direction of weld

NOTES
1. Porosity is to be determined in accordance with ISO 10042. The requirements for a single gas pore are to be met by all the gas pores within this circle. Systematic clustered porosity is not permitted.
2. If several oxide inclusions l_1, l_2, l_3, ... exist in one cross-section, then they are summed: $l = l_1 + l_2 + l_3 + ... + l_n$.

Plastics Materials and other Non-Metallic Materials

■ *Section 1* General requirements

1.1 Scope

1.1.1 Provision is made in this Chapter for the manufacture and testing of plastics pipes, together with approval requirements for base materials used in the construction or repair of composite vessels, other marine structures, piping and any associated machinery components and fittings which are to be certified or are intended for classification.

1.1.2 These materials and products are to be manufactured and surveyed in accordance with the general requirements of Sections 1, 2 and 3 of this Chapter; and LR's *Materials and Qualification Procedures for Ships (MQPS) Book K*, *see* Ch 1,2.2.2, which, in addition to the test programme, also details the procedures for application for approval of manufacturers and products and details of the information to be supplied by the manufacturer.

1.1.3 For base materials, the manufacturer's works do not require approval by Lloyd's Register (hereinafter referred to as 'LR'), however the Quality Control procedures must be acceptable in accordance with the appropriate Section of this Chapter.

1.1.4 Where a requirement exists for the material to be approved, the test requirements and information to be submitted for approval of polymers, resins, reinforcements and associated materials are defined in Sections 2 and 3.

1.1.5 Specific material requirements relating to the design and manufacture of plastics pipes and fittings are indicated in Section 4, with the material requirements for hull structures contained in Section 5.

1.1.6 For Builders constructing composite vessels, Section 5 provides the minimum material control requirements for acceptance of the works by LR.

1.1.7 For the purposes of these Rules a 'plastics material' is regarded as an organic substance which may be thermosetting or thermoplastic and which, in its finished state, may contain reinforcements or additives.

1.1.8 Materials not listed in 2.1.1 may be considered for approval on a case-by-case basis. The approved test results will be listed on the issued certificate. Subject to satisfactory service experience and validation of approval, the material may be entered in 2.1.1 of the Rules.

1.2 Information on material quality and application

1.2.1 Where plastics products are to be classed or certified, the manufacturer is to provide the material producer with such information as is essential to ensure that the base materials to be used are in accordance with the approval requirements and the product specification. This information is to include any survey requirements for the materials.

1.3 Manufacture

1.3.1 Plastics products are to be made at works which have been approved (or accepted) for the type of product being supplied using base materials that have been approved.

1.3.2 Base materials are to be approved in accordance with the requirements of Sections 2 and 3.

1.3.3 In order that a works can be approved (or accepted), the manufacturer is required to demonstrate to the satisfaction of LR that the necessary manufacturing and testing facilities are available and are supervised by qualified personnel. A specified programme of tests is to be carried out under the supervision of the Surveyors, and the results are to be to the satisfaction of LR. When a manufacturer has more than one works, the approval (or acceptance) is only valid for the individual works which carried out the test programme.

1.3.4 In order to maintain approval, the manufacturer is required to confirm in writing that there have been no changes in the formulation or production process for the material in question and that the site of manufacture remains unchanged.

1.4 Survey procedure

1.4.1 The Surveyors are to be allowed access to all relevant parts of the works and are to be provided with the necessary facilities and information to enable them to verify that manufacture is being carried out in accordance with the approved procedure. Facilities are also to be provided for the selection of test material, the witnessing of specified tests and the examination of materials, as required by the Rules.

1.4.2 Prior to the provision of test material for acceptance, manufacturers are to provide the Surveyors with details of the order, specification and any special conditions additional to the Rule requirements.

1.4.3 Before final acceptance, all test materials are to be confirmed as typical of the manufactured product and be submitted to the specified tests and examinations under conditions acceptable to the Surveyors. The results are to comply with the specification and any Rule requirements and are to be to the satisfaction of the Surveyors.

1.4.4 These specified tests and examinations are to be carried out prior to the despatch of finished products from the manufacturer's works.

1.4.5 In the event of any material proving unsatisfactory, during subsequent working, machining or fabrication, it is to be rejected, notwithstanding any previous certification.

1.5 Alternative survey procedure

1.5.1 Where materials are manufactured in quantity by semi-continuous or continuous processes under closely controlled conditions, an alternative system for testing and inspection may be adopted, subject to the agreement of the Surveyors.

1.5.2 In order to be considered for approval, manufacturers are to comply with the requirements of Ch 1,2.

1.6 Post-cure heating

1.6.1 Post-cure heating is to be carried out in properly constructed ovens which are efficiently maintained and have adequate means for control and recording of temperature. The oven is to be such as to allow the whole item to be uniformly heated to the necessary temperature. In the case of very large components which require post-cure heating, alternative methods will be specially considered.

1.7 Test material

1.7.1 Sufficient material is to be provided for the preparation of the test specimens detailed in the specific requirements. It is, however, in the interests of manufacturers to provide additional material for any re-tests which may be necessary, as insufficient or unacceptable test material may be a cause for rejection.

1.7.2 Where test materials, (either base materials or product sample materials) are selected by the Surveyor or a person nominated by LR, these are to be suitably identified by markings which are to be maintained during the preparation of the test specimens.

1.7.3 All base material samples for testing are to be prepared under conditions that are as close as possible to those under which the product is to be manufactured. Where this is not possible, a suitable procedure is to be agreed with the Surveyor.

1.7.4 During production, check test samples are to be provided as requested by the Surveyor.

1.7.5 Should the taking of these samples prove impossible, model samples are to be prepared concurrently with production. The procedure for the preparation of these samples is to be agreed with the Surveyor.

1.7.6 The dimensions, number and orientation of test specimens are to be in accordance with the requirements of a National or International Standard acceptable to LR.

1.8 Re-test procedure

1.8.1 Where test material fails to meet the specified requirement, two additional tests of the same type may be made at the discretion of the Surveyor.

1.8.2 Where an individual test result in a group, (minimum five) deviates from the mean by more than two standard deviations in either the higher or lower direction, the result is to be excluded and a re-test made. Excluded results of tests are to be reported with confirmation that they have been excluded. Only one exclusion is acceptable in any group of tests.

1.9 Visual and non-destructive examination

1.9.1 Prior to the final acceptance, surface inspection, verification of dimensions and non-destructive examination are to be carried out in accordance with the requirements detailed in Sections 3, 4 and 5 of this Chapter.

1.9.2 When there is visible evidence to doubt the soundness of any material or component, such as flaws or suspicious surface marks, it is to be the responsibility of the manufacturer to prove the quality of the material by any suitable method.

1.10 Rectification of defective material

1.10.1 Small surface blemishes may be removed by mechanical means provided that, after such treatment, the dimensions are acceptable, the area is proved free from structural defects and the rectification has been completed to the satisfaction of the Surveyor.

1.10.2 Repair procedures for larger defects are to be agreed with LR prior to implementation.

1.11 Identification of products and base materials

1.11.1 The manufacturer of approved materials is to identify each batch with a unique number.

1.11.2 The manufacturer of plastics products is to adopt a system of identification which will enable all finished products to be traced to the original batches of base materials. Surveyors are to be given full facilities for tracing any component or material when required.

1.11.3 When any item has been identified by the personal mark of a Surveyor, or deputy, this is not to be removed until an acceptable new identification mark has been made by a Surveyor. Failure to comply with this condition will render the item liable to rejection.

1.11.4 Before any pipe or fitting is finally accepted it is to be clearly marked by the manufacturer in at least one place with the particulars detailed in the appropriate specific requirements as given in Section 4.

1.11.5 Where a number of identical items are securely fastened together in bundles, the manufacturer need only brand the top item of each bundle. Alternatively, a durable label giving the required particulars may be attached to each bundle.

1.12 Certification

1.12.1 Certification of the finished product is to be in accordance with the requirements of the appropriate Sections.

■ *Section 2*
Tests on polymers, resins, reinforcements and associated materials

2.1 Scope

2.1.1 This Section gives the tests and data required by LR for materials approval and/or inspection purposes on the following:
(a) Thermoplastic polymers.
(b) Thermosetting resins.
(c) Reinforcements.
(d) Reinforced thermoplastic polymers.
(e) Reinforced thermosetting resins.
(f) Core materials.
 (i) End-grain balsa.
 (ii) Rigid foams.
 (iii) Synthetic felt type materials.
(g) Machinery chocking compounds.
(h) Rudder and pintle bearings.
(j) Stern tube bearings.
(k) Plywoods.
(l) Adhesive and sealant materials.
(m) Repair compounds.

2.2 Thermoplastic polymers

2.2.1 The following data is to be provided by the manufacturer for each thermoplastic polymer:
(a) Melting point.
(b) Melt flow index.
(c) Density.
(d) Bulk density.
(e) Filler content, where applicable.
(f) Pigment content, where applicable.
(g) Colour.

2.2.2 Samples for testing are to be prepared by moulding or extrusion under the polymer manufacturer's recommended conditions.

2.2.3 The following tests are to be carried out on these samples:
(a) Tensile stress at yield and break.
(b) Modulus of elasticity in tension.
(c) Tensile strain at yield and break.
(d) Compressive stress at yield and break.
(e) Compressive modulus.
(f) Temperature of deflection under load.
(g) Determination of water absorption.

2.3 Thermosetting resins

2.3.1 The data listed in Table 14.2.1 is to be provided by the manufacturer for each thermosetting resin.

Table 14.2.1 Data requirements for thermosetting resins

Data	Type of resin		
	Polyester (*see* Note 3 for vinylester)	Epoxide	Phenolic
Specific gravity of liquid resin	required	required	required
Viscosity	required	required	required
Gel time	required	required	not applicable
Appearance	required	required	required
Mineral content (*see* Note 1)	required	required	not applicable (*see* Note 2)
Volatile content	required	not applicable	not applicable
Acid value	required	not applicable	not applicable
Epoxide content	not applicable	required	not applicable
Free phenol	not applicable	not applicable	required
Free formaldehyde	not applicable	not applicable	required

NOTES
1. This is to be the total filler in the system, including thixotrope, filler, pigments, etc., and is to be expressed in parts by weight per hundred parts of pure resin.
2. If the resin is pre-filled, the mineral content is required.
3. Vinylesters are to be treated as equivalent to polyesters.

2.3.2 Cast samples are to be prepared in accordance with the manufacturer's recommendations and are to be cured and post-cured in a manner consistent with the intended use. The curing system used and the ratio of curing agent (or catalyst) to resin are to be recorded. Where post-cure conditions equivalent to ambient-cure conditions apply, *see* 3.2.2 and 3.2.3.

2.3.3 The following are to be determined using these samples:

(a) Tensile strength (stress at maximum load) and stress at break.
(b) Tensile strain at maximum load.
(c) Tensile secant modulus at 0,5 per cent and 0,25 per cent strain respectively.
(d) Temperature of deflection under load.
(e) Barcol hardness.
(f) Determination of water absorption.
(g) Volume shrinkage after cure.
(h) Specific gravity of cast resin.

2.3.4 In addition, for gel coat resins the stress at break and modulus of elasticity in flexure are to be determined.

2.3.5 Where resins which have been modified by the addition of waxes or polymers, for example 'low styrene emission or air inhibited' materials, it is to be confirmed that the use of such resins will not result in poor interlaminar adhesion when interruptions to the laminating process occur. The test procedure is to be as follows:

(a) A conventional room temperature curing catalyst/ accelerator system is to be used with the resin for laminate preparation.
(b) A laminate of 25 to 35 per cent glass content in mass is to be prepared using two plies of 450 g/m^2 chopped strand mat. The laminate is to be prepared at ambient temperature (18° to 21°C). The laminate is to be allowed to stand for a minimum of four days but no longer than 6 days at ambient temperature.
(c) A further two plies of 450 g/m^2 chopped strand mat are to be laminated onto the exposed surface and cured at ambient temperature for 24 hours. The finished laminate is then to be post-cured at 40°C for 16 hours. The finished laminate is to have a glass content of 25 to 35 per cent.
(d) After cooling, the apparent interlaminar shear strength of the laminate is to be determined in accordance with ISO 14130; the minimum value is given in Table 14.5.5. Before testing the samples shall be conditioned at 23°C and relative humidity of 50 per cent for a period of 88 hours before testing.
(e) If the tests are undertaken at the resin manufacturer's own laboratory, the individual test values are to be reported and the broken test specimens retained for examination by LR.

Alternative test procedures will be considered with prior agreement.

2.4 Reinforcements

2.4.1 The following data is to be provided, where applicable, for each type of reinforcement:

(a) Reinforcement type.
(b) Fibre type for each direction.
(c) Fibre tex value.
(d) Fibre finish and/or treatment.
(e) Yarn count in each direction.
(f) Width of manufactured reinforcement.
(g) Weight per unit area of manufactured reinforcement.
(h) Weight per linear metre of manufactured reinforcement.
(j) Compatibility (e.g. suitable for polyesters, epoxides, etc.).
(k) Constructional stitching – details of yarn, specific gravity, type, frequency and direction.
(l) Weave type.
(m) Binder type and content.
(n) Density of the fibre material.

2.4.2 Tests of the mechanical properties are to be made on laminate samples containing the reinforcement and prepared as follows:

(a) an approved resin of suitable type is to be used;
(b) a minimum of three layers of the reinforcement is to be laid with parallel ply to give a laminate not less than 4 mm thick;
(c) the weights of resin and reinforcement used are to be recorded together with the measured thickness of the laminate, including the measured weight per unit area of the reinforcement used;
(d) for glass reinforcements, the glass/resin ratios, by weight, as shown in Table 14.2.2 are to be used;
(e) for reinforcement type other than glass, a fibre volume fraction, as shown in Table 14.2.3, is to be used.

Table 14.2.2 Glass fraction by weight for different reinforcement types

Reinforcement type	Glass fraction nominal values
Unidirectional	0,60
Chopped strand mat	0,30
Woven roving	0,50
Woven cloth	0,50
Composite roving (*see* Note)	0,45
Gun rovings	0,33
±45° stitched parallel plied roving	0,50
Triaxial parallel plied roving	0,50
Quadriaxial parallel plied roving	0,50
NOTE Continuous fibre reinforcement with attached chopped strand mat.	

2.4.3 Rovings intended for filament winding are to be tested as unidirectional rovings.

2.4.4 The following tests as defined in Section 3 are to be made on the samples:

(a) Tensile strength (stress at maximum load).
(b) Tensile strain at break.
(c) Tensile secant modulus at 0,5 per cent and 0,25 per cent strain respectively.
(d) Compressive strength (stress at maximum load).
(e) Compressive modulus.
(f) Flexural strength (stress at maximum load).
(g) Modulus of elasticity in flexure.
(h) Apparent interlaminar shear.

Table 14.2.3 Content by volume for different reinforcement types

Reinforcement type	Content by volume nominal values
Unidirectional	0,41
Chopped strand mat	0,17
Woven roving	0,32
Woven cloth	0,32
Composite roving (*see* Note)	0,28
Gun rovings	0,19
±45° stitched parallel plied roving	0,32
Triaxial parallel plied roving	0,32
Quadriaxial parallel plied roving	0,32

NOTE
The volume content may be converted to weight fractions by use of the formula:

$W_F = V_F D_F/(D_F V_F + D_R V_R)$

where

W_F = fibre fraction by weight
D_F = density of fibre
D_R = density of cured resin
V_F = fibre fraction by volume
V_R = resin fraction by volume

(j) Fibre content.
(k) Determination of water absorption.

2.4.5 The laminate is to be tested in air in the directions indicated by Table 14.2.4.

Table 14.2.4 Fibre orientations in reinforced test specimens

Type of reinforcement	Test orientations
Unidirectional	0°
Chopped strand mat Gun roving	any direction
Woven roving Woven cloth Composite roving	0° and 90°
± 45° parallel plied roving Triaxial plied roving Quadriaxial plied roving	0°, 45°, 90° and –45°

2.4.6 Additionally, tests in 2.4.4(c) and (f) are to be repeated, in one direction only, after immersion in fresh water at 35°C for 28 days with the exception of 2.4.4(k).

2.5 Reinforced thermoplastic polymers

2.5.1 Thermoplastic polymers intended for use with reinforcements are to be tested in accordance with 2.2.1 to 2.2.3.

2.5.2 A laminate is to be prepared using the polymer and an approved reinforcement in accordance with a manufacturing specification. The laminate is to be tested in accordance with the appropriate requirements of 2.4.4. Testing may be confined to one direction only.

2.6 Reinforced thermosetting resins

2.6.1 Thermosetting resins intended for use with reinforcements are to be tested in accordance with 2.3.1 to 2.3.4.

2.6.2 No further tests are required for gel coat resins.

2.6.3 For laminating resins, a laminate is to be prepared using the resin and an approved reinforcement as follows:
(a) For polyester resins, chopped strand mat.
(b) For epoxide resins, a balanced woven roving.
(c) For phenolic resins, a balanced woven material.

2.6.4 The laminate is to be tested in accordance with procedures outlined in MQPS Book K procedure 14-1 and 2.4.4 in one fibre direction only.

2.7 Core materials

2.7.1 **General requirements**. The following data is to be provided for each type of core material:
(a) Type of material.
(b) Density.
(c) Description (block, scrim mounted, grooved).
(d) Thickness and tolerance.
(e) Sheet/block dimensions.
(f) Surface treatment.

2.7.2 Manufacturers are required to provide a full application procedure for use of the product.

2.8 Specific requirements for end-grain balsa

2.8.1 The supplier is to provide a signed statement that the balsa (ochroma lozopus) is cut to end-grain, is of good quality, being free from unsound or loose knots, holes, splits, rot, pith and corcho, and that it has been treated against fungal and insect attack, shortly after felling, followed by homogenisation, sterilisation and kiln drying to an average moisture content of no more than 12 per cent.

2.8.2 The following tests are to be carried out on the virgin material, both parallel to and perpendicular to the grain:
(a) Compressive strength (stress at maximum load).
(b) Compressive modulus of elasticity.
(c) Tensile strength (stress at maximum load).
The density of the virgin material is also to be tested.

2.8.3 Where the balsa is mounted on a carrier material (e.g. scrim), any adhesive used is to be of a type compatible with the proposed resin system.

2.8.4 Core shear properties are to be determined according to the requirements of 3.8.1.

2.9 Specific requirements for rigid foams (PVC, Polyurethane and other types)

2.9.1 The foam is to be of the closed cell type and compatible with the proposed resin system (e.g., polyester, epoxide, etc.).

2.9.2 Foams are to be of uniform cell structure.

2.9.3 Data is to be provided on the dimensional stability of the foam by measurement of the shrinkage.

2.9.4 The following test data is to be submitted for each type of foam:
(a) Density.
(b) Tensile strength (stress at maximum load).
(c) Tensile modulus of elasticity.
(d) Compressive strength (stress at maximum load).
(e) Compressive modulus of elasticity.

2.9.5 Core shear properties are to be determined according to the requirements of 3.8.1.

2.9.6 Additionally, the compressive properties (*see* 2.9.4(d) and (e)) are to be determined at a minimum of five points over the temperature range ambient to maximum recommended service or 70°C, whichever is the greater.

2.10 Synthetic felt type materials with or without microspheres

2.10.1 For materials of this type, the following data is required in addition to the requirements of 2.7.1:
(a) Fibre type.
(b) Width.
(c) Width of finished material.
(d) Weight per unit area of the manufactured material.
(e) Weight per linear metre of the manufactured material.
(f) Compatibility.
(g) Details of the method of combining.

2.10.2 A laminate of the material is to be prepared using a suitable approved resin under conditions recommended by the manufacturer.

2.10.3 The following properties are to be determined:
(a) Tensile strength (stress at maximum load).
(b) Tensile strain at break.
(c) Modulus of elasticity in tension or secant modulus at 0,25 per cent and 0,5 per cent strain.
(d) Compressive strength (stress at maximum load).
(e) Compressive modulus.
(f) Flexural strength (stress at maximum load).
(g) Modulus of elasticity in flexure.
(h) Fibre content.
(j) Water absorption.

2.10.4 In the case of anisotropic materials (e.g., where combined with other reinforcements) the tests listed in 2.10.3 are to be conducted in the 0°, 90° directions and in any other reinforcement direction.

2.10.5 Additionally, the tests listed in 2.10.3 are to be repeated after immersion in fresh water at 35°C for 28 days. For anisotropic materials, the requirement is for this test to be carried out in one direction only.

2.10.6 The shear properties (of the resin filled system) are to be determined according to 3.8.1.

2.11 Machinery chocking compounds (resin chocks)

2.11.1 Thermosetting materials for filling the space between the base of machinery and its foundation where the maintenance of accurate alignment is necessary are to be approved by LR before use.

2.11.2 Approval will be considered by LR for use under the following service conditions:
- Loading of 3,5 N/mm^2 (max) for a temperature not exceeding 60°C.
- Loading of 2,5 N/mm^2 (max) for a temperature not exceeding 80°C.
- Other loading conditions.

2.11.3 The exotherm temperature, defined as the maximum temperature achieved by the reacting resin under conditions equivalent to those of intended use, is to be determined according to a procedure approved by LR.

2.11.4 The following properties are to be determined on chock material cured at the measured exotherm temperature:
(a) The impact resistance (Izod).
(b) Hardness.
(c) Compressive strength (stress at maximum load) and modulus of elasticity.
(d) Water absorption.
(e) Oil absorption.
(f) Heat deflection temperature.
(g) Compressive creep is to be measured according to 3.9.4.
(h) Curing linear shrinkage.
(j) Flammability.

2.11.5 The chocking compound approval is contingent on the material achieving the minimum exotherm value as specified when used on an installation under practical conditions.

2.11.6 Where the resin chock is to be used for installation of sterntubes and sternbushes in addition to the requirements of 2.11.4, the tensile strength and modulus of elasticity in tension are to be measured.

2.11.7 The manufacturer's installation procedure is required to be documented and is to be to the satisfaction of LR.

2.12 Rudder and pintle bearings

2.12.1 Materials used for rudder and pintle bearings are to be approved by LR before use.

2.12.2 Initial approval is to be based on a review of the following physical properties of the material:

(a) Compressive strength (stress at maximum load) and modulus of elasticity.
(b) Tensile strength (stress at maximum load) and modulus of elasticity.
(c) Shear strength (stress at maximum load).
(d) Impact strength.
(e) Swelling in oil and in water.
(f) Hardness.

2.12.3 Additionally, friction data is to be provided under both wet and dry conditions.

2.12.4 Furthermore, the installation instructions (especially recommended clearances) are to be reviewed by LR prior to provisional approval being given.

2.12.5 If the above data is satisfactory, the material will be provisionally approved until sufficient service experience has been gained.

2.13 Sterntube bearings

2.13.1 Materials used for sterntube bearings are to be approved by LR before use.

2.13.2 Approval is to be based on a review of the physical properties as given by 2.12.2.

2.13.3 Friction data is to be provided under the lubrication system(s) proposed for the material(s).

2.14 Plywoods

2.14.1 All plywoods are to be approved to BS 1088 or equivalent National or International Standard in accordance with LR's Type Approval Procedure.

2.14.2 For structural applications in the marine environment, a minimum timber rating of moderate durability according to BS 1088-1 and BS 1088-2 is required.

2.14.3 Enhancement of durability by use of preservatives is permitted, subject to each veneer layer being treated with a recognised preservative.

2.14.4 Where Okoume, as specified by BS 1088 is involved, (i.e. non-durable timber classification) this may only be used for marine structures subject to the specific application being acceptable to LR.

2.15 Adhesive and sealant materials

2.15.1 Materials of these types are to be accepted by LR before use.

2.15.2 The requirements for acceptance are dependent on the nature of the application.

2.15.3 In the first instance, the manufacturer is to submit full details of the product, procedure for method of use (including surface preparation) and the intended application. After review of these details, LR will provide a specific test schedule for confirmation of the material's properties.

2.15.4 Any acceptance granted will be limited to specific applications and will be contingent on the instructions for use being adhered to.

2.16 Repair compounds

2.16.1 Materials used for repairs are to be accepted by LR before use.

2.16.2 For acceptance purposes, the manufacturer is to submit full product details, and user instructions, listing the types of repair for which the system is to be used together with details of any installer accreditation schemes.

2.16.3 Dependent on the proposed uses, LR may require testing in accordance with a specified test programme.

2.16.4 Materials will not be accepted for the following uses unless specific evidence of their suitability is provided:

(a) Any component in rubbing contact.
(b) Any component subject to dynamic cyclic loading.
(c) Any pressure part in contact with gas or vapour.
(d) Any pressure part in contact with liquid above 3,5 bar.
(e) Any component where operating temperature exceeds 90°C.

All uses of materials of these types are subject to the discretion of the Surveyor.

■ *Section 3* Testing procedures

3.1 General

3.1.1 This Section gives details of the test methods to be used for base materials and on finished plastics products such as fibre reinforced plastics (FRP) piping and any testing required in the construction of composite vessels.

3.1.2 In general, testing is to be carried out by a competent independent test house which, at the discretion of LR, may or may not require witnessing by the Surveyor.

3.1.3 Alternatively, testing may be carried out by the manufacturer subject to these tests being witnessed by the Surveyor.

3.1.4 All testing is to be carried out by competent personnel.

3.1.5 Unless specified otherwise, testing is to be carried out in accordance with a recognised ISO Standard, where one exists, and all test programmes are to have written procedures.

3.1.6 Alternatively, testing may be carried out in accordance with a National Standard provided that it conforms closely to an appropriate ISO standard and subject to prior agreement with the Surveyor.

3.1.7 Mechanical properties are to be established using suitable testing machines of approved types. The machines and other test equipment are to be maintained in a satisfactory and accurate condition and are to be recalibrated at approximately annual intervals. Calibration is to be undertaken by a nationally recognised authority or other organisation of standing and is to be to the satisfaction of the Surveyor. A record of all calibrations is to be kept available in the test house. The accuracy of test machines is to be within ±one per cent.

3.2 Preparation of test samples

3.2.1 Thermoplastic samples are to be prepared in accordance with the manufacturer's recommendations for moulding. For finished products, samples are to be taken from the product during production in accordance with the manufacturer's quality plan, but where this is impractical, separate test samples are to be prepared in a manner identical with that of the product.

3.2.2 Samples of thermosetting resins are to be prepared using the curing system recommended by the manufacturer and identical with that used for the finished product.

3.2.3 The post curing conditions for samples of thermosetting resins are to be as recommended by the manufacturer and identical with those used for the finished product. Where the samples are made for the general approval of a resin, the post curing conditions are to be those in which the resin is intended to be used.

3.2.4 Where curing of the product is intended to take place at room temperature, the sample is to be allowed to cure at room temperature (18 to 21°C) for 24 hours followed by a post-cure at 40°C for 16 hours.

3.2.5 Where a reinforcement is to be used, the ratio of reinforcement to resin or polymer is to be nominally the same as that of the finished product or in accordance with Table 14.2.2 or 14.2.3.

3.2.6 Where laminates are prepared specifically for approval test purposes, the reinforcement is to be laid parallel plied.

3.3 Preparation of test specimens

3.3.1 The test specimen is to be prepared in accordance with the appropriate ISO standard and the requirements of this Section.

3.3.2 Precautions are to be taken during machining to ensure that the temperature rise in the specimen is kept to a minimum.

3.4 Testing

3.4.1 Strain measurement is to be made by the use of a suitable extensometer or strain gauge.

3.4.2 The rate of strain is to be in accordance with the appropriate ISO standard.

3.4.3 The number of test specimens from each sample to be tested is to be in accordance with the ISO standard. For mechanical testing this is five.

3.5 Discarding of test specimens

3.5.1 If a test specimen fails because of faulty preparation or incorrect operation of the testing machine, it is to be discarded and replaced by a new specimen.

3.5.2 In addition, if the deviation of one result in a group of five exceeds the mean by more than two standard deviations, that result is to be discarded and one further specimen tested, *see* 1.8.1 and 1.8.2.

3.6 Reporting of results

3.6.1 All load/displacement graphs and tabulated results are to be reported, including mean values and the calculated standard deviation.

3.6.2 Additionally, full details of the sample and specimen preparation are to be provided including (where applicable):
(a) Catalyst/accelerator or curing agent types and mix ratio.
(b) Weights of resins, and/or reinforcements used.
(c) Casting/laminate dimensions.
(d) Number of layers of reinforcement used.
(e) Curing/post-curing conditions.

3.7 Tests for specific materials

3.7.1 The data requirements in 2.2 and 2.3 for thermoplastic or thermosetting resins or polymers are to be determined in accordance with suitable National or International Standards.

3.7.2 Recognised Standards to which specimens of unreinforced thermoplastic resins are to be tested are listed in Table 14.3.1.

3.7.3 Test standards for unreinforced cast thermosetting resins are given in Table 14.3.2.

3.7.4 The Standards to which laminate specimens of any type are to be tested are listed in Table 14.3.3.

Table 14.3.1 Tests for unreinforced thermoplastic resins

Test	Standard	
Tensile properties	ISO 527-2:1993	Test speed = 5 mm/min Specimen 1A or 1B
Flexural properties	ISO 178:2001	Test speed = $\frac{\text{Thickness}}{2}$ mm/min
Water absorption	ISO 62:2008	Method 1
Temperature of deflection under load	ISO 75-2:2004	Method A
Compressive properties	ISO 604:2002	Test speed – as for ductile materials

NOTES
1. Water absorption – result to be expressed as milligrams.
2. Tensile modulus values are to be determined using an extensometer which may be removed for strain to failure.

Table 14.3.2 Tests on unreinforced cast thermoset resin specimens

Test	Standard	
Tensile properties	ISO 527-2:1993	Test speed = 5 mm/min Specimen 1A or 1B
Flexural properties	ISO 178:2001	Test speed = $\frac{\text{Thickness}}{2}$ mm/min
Water absorption	ISO 62:2008	Method 1
Temperature of deflection under load	ISO 75-2:2004	Method A
Compressive properties	ISO 604:2002	Test speed = 1 mm/min

NOTES
1. ISO 62:2008 – where resins are intended for use under ambient conditions to avoid additional post-curing, the requirement in ISO 62:2008 for pre-drying the test specimen at 50°C is to be omitted. The test result is to be expressed as mg of water.
2. ISO 527-2:1993 – tensile properties are to be measured using extensometry.

3.8 Structural core materials

3.8.1 Initially, the core shear strength and modulus are to be determined by ISO 1922:2001 or ASTM C273/C273M. Test sandwich panels are then to be prepared and subjected to four-point flexural tests to determine the apparent shear properties according to ASTM C393/C393M:06 (short beam) at two representative thicknesses (i.e., 15 mm and 30 mm). Testing is to be carried out at ambient temperature and at 70°C. The following requirements are to be observed:

Table 14.3.3 Tests on laminate specimens

Test	Standard	
Tensile properties	ISO 527-4:1997	Test speed = 2 mm/min Specimens Types II or III
Flexural properties	ISO 14125:1998	Test speed = $\frac{\text{Thickness}}{2}$ mm/min Method A
Compressive properties	ISO 604:2002	Test speed = 1 mm/min
Interlaminar shear	ISO 14130:1997	
Water absorption	ISO 62:2008	Method 1
Glass content	ISO 1172:1996	

NOTES
1. ISO 62:2008 – where resins are intended for use under ambient conditions to avoid additional post-curing, the requirement in ISO 62:2008 for pre-drying the test specimen at 50°C is to be omitted. The test result is to be expressed as mg of water.
2. ISO 527-4:1997 – tensile properties are to be measured using extensometry.
3. Tensile modulus values are to be determined using an extensometer which may be removed for strain to failure.

(a) Each skin is to be identical and have a thickness not greater than 21 per cent of the nominal core thickness. For hand laid constructions, each skin is to comprise a lightweight chopped strand mat reinforcement (300 g/m^2) consolidated at a glass content, by weight, of 0,3 against the core, plus the required number of woven reinforcements consolidated, using an isophthalic polyester resin, to give a minimum glass content, by weight, of 0,5.
(b) The method of construction of the sandwich laminate is to reflect the core material manufacturer's instructions for use, i.e., application of bonding paste, surface primer or any other recommended system.
(c) Where vacuum bagging techniques or equivalent systems are used, these will be subject to individual consideration.
(d) All resins and reinforcements are to hold current LR approval.
(e) Curing conditions are to be in accordance with 3.2.3 and 3.2.4.
(f) The dimensions of the test samples should be based on the requirements of ASTM C393 Paragraph 5.1, and the ratio parameters as indicated in ASTM C393 Paragraph 5.2, using a proportional limit stress (*F*) for the woven roving skins of 130 N/mm^2 and a span (a_2) of not less than 400 mm.

3.8.2 For each type of test sample, the following data are to be reported, together with the submission of a representative test sample showing the mode of failure for each density of core material:

(a) Skin and core thickness, and core type and density.
(b) Resin/catalyst/accelerator ratio.
(c) Skin construction, including types and weight of reinforcements, resin(s), etc.
(d) Details of production method and curing conditions (temperature and times).
(e) Where additional preparation of the foam is involved, for example the use of primers or bonding pastes, full details are to be provided.
(f) Actual span between base supports for each type of test sample.

3.8.3 The following requirements apply to end-grain balsa:

(a) The data requirements of 2.7.1 are to be provided, where applicable, according to suitable National or International Standards.
(b) The balsa is to be tested according to the requirements of 3.8.1.
(c) The test methods for balsa are given in Table 14.3.4.

Table 14.3.4 Tests on end-grain balsa

Test	Standard
Density	ISO 845:2006
Tensile properties	ASTM C297/C297M:04 Test speed = $\frac{\text{Thickness}}{10}$ mm/min
Compressive properties	ISO 844:2007 Test speed = $\frac{\text{Thickness}}{10}$ mm/min
Shear properties	ISO 1922:2001 Test speed = 1mm/min

3.8.4 The following requirements apply to rigid foams:

(a) The data requirements of 2.7.1 are to be provided in accordance with a suitable National or International Standard.
(b) The foam is to be tested according to the requirements of 3.8.1.
(c) The test methods for rigid foams are to be in accordance with Table 14.3.4.

3.8.5 The following requirements apply to synthetic felt type materials:

(a) The data requirements of 2.10.1 are to be provided according to suitable National or International Standards.
(b) The material is to be tested according to the requirements of 3.8.1, with the following modifications:
    (i) The core of the laminate test sandwich panel is to be prepared with a fibre content as recommended by the manufacturer.
    (ii) The felt fibre/resin ratio is to be stated.
    (iii) The required test thicknesses of the cores are to be changed from 30 mm and 15 mm to 12 mm and 6 mm respectively.
(c) The prepared laminate of the base material is to be of minimum thickness 3,5 mm with a minimum of three layers.
(d) The specified tests on the laminate (*see* 2.10.3) are to be conducted according to the requirements of Table 14.3.3.

3.9 Machinery chocking compounds

3.9.1 Test samples of the cured chock resin are to be prepared under ambient conditions and then post-cured at the exotherm temperature as determined in 2.11.3.

3.9.2 The specified properties are to be determined as required by Table 14.3.5.

Table 14.3.5 Tests for machinery chocking compounds

Test	Standard
Izod Impact Resistance	ISO 180-2000 Unnotched
Barcol hardness	ASTM D2583-07 or BS 2782 part 10 Method 1001
Compressive strength	ISO 604:2002 Test speed = 1 mm/min
Water absorption	ISO 62:2008 Method 1 25 mm x 20 mm cylinder (to constant weight)
Oil absorption (light machine)	ISO 175:1999 25 mm x 20 mm cylinder (to constant weight)
Temperature of deflection under load	ISO 75-2 Method A

3.9.3 The percentage linear shrinkage of cured material is to be measured.

3.9.4 Creep is to be measured according to the following method:

(a) A 25 mm x 20 mm diameter parallel faced cylinder is to be pre-loaded against a steel base at 2,5 N/mm^2 or 3,5 N/mm^2, or at the specified higher loading condition, at ambient temperature for 16 hours.
(b) The temperature is to be increased at the rate of 8°C per hour until the service temperature (60°C or 80°C) is reached.
(c) During this time, the creep of the cylinder is to be measured at 15 minute intervals.
(d) The temperature and loading are to be maintained for a minimum of 100 days measuring the creep at intervals of 24 hours.
(e) A plot of creep in mm (linear scale) against time (log scale), together with full experimental details, is to be provided for review by LR.

3.10 Rudder and pintle bearings

3.10.1 All mechanical properties as required by 2.12 are to be measured according to suitable National or International Standards.

3.10.2 Frictional properties are to be determined according to a method agreed with LR.

3.11 Sterntube bearings

3.11.1 The requirements for sterntube bearings are as defined in 2.13.

■ *Section 4* Plastics pipes and fittings

4.1 Scope

4.1.1 This Section gives the general requirements for plastics pipes and fittings, with or without reinforcement, intended for use in the services listed in the relevant Rules dealing with design and construction. Hoses and mechanical couplings are not covered by these requirements.

4.1.2 Pipes and fittings intended for application in Class I, Class II and Class III systems for which there are Rule requirements, are to be manufactured in accordance with the requirements of Section 1 and this Section.

4.1.3 As an alternative to 4.1.2, plastics pipes and fittings which comply with National or proprietary specifications may be accepted, provided that the specifications give reasonable equivalence to the requirements of this Section or, alternatively, are approved for a specific application. The survey and certification are however to be carried out in accordance with the requirements of this Section.

4.2 Design requirements

4.2.1 The requirements for design approval are detailed in the relevant Rules.

4.2.2 The design submission is to include a materials list with confirmation that the materials listed have properties and characteristics conforming with those values used in the design submission. As a minimum, the details given should include the following:

(a) Resin.
(b) Accelerator (type and concentration).
(c) Catalyst or curing agent (type and concentration).
(d) Reinforcement.
(e) Cure/post-cure conditions.
(f) Resin/reinforcement ratio.
(g) Wind angle (or lay-up sequence) and orientation.
(h) Dimensions and tolerances.

This submission is to include similar details for the fittings together with a description of the method of attachment of the fittings to the pipes.

4.2.3 Any alteration of the component materials or manufacturing operations from those used in the design submission will necessitate a completely new submission.

4.2.4 If the piping manufacturer anticipates the possible use of alternative materials, these should be listed in the design submission. Proof that the modified product will meet the specified requirements will be needed prior to its use.

4.3 Manufacture

4.3.1 Plastics pipes and fittings intended for use in Class I, Class II and Class III systems are to be manufactured at facilities approved by LR, using materials approved by LR.

4.3.2 A Manufacturing Specification is to be submitted. This is to contain details of the following:

(a) All constituent materials.
(b) Manufacturing procedures such as lay-up sequence or wind angle, the ratios of curing agent to resin and reinforcement to resin, the laminate thickness, the mandrel dwell time (initial cure) and the cure and post-cure conditions.
(c) Quality control procedures including details and frequency of tests on the incoming materials, tests made during production and on the finished piping.
(d) Acceptance standards and tolerances, including all dimensions.
(e) Procedures for cosmetic repair.
(f) System for traceability of the finished piping to the batches of raw materials.
(g) Method of bonding pipes and fittings.

4.3.3 Details of all raw materials are to be submitted for approval and are to be in accordance with the Manufacturing Specification and the design submission.

4.3.4 All batches of raw materials are to be provided with unique identifications by their manufacturers.

4.3.5 No batch of material is to be used later than its date of expiry.

4.3.6 The piping manufacturer is to ensure that all batches of materials are used sequentially.

4.3.7 The piping manufacturer is to maintain records of the amounts of resin and reinforcement used, in order to ensure that the proportions remain within the limits set in the Manufacturing Specification.

4.3.8 Records are to be kept of the wind angle and/or the orientation of the reinforcement.

4.3.9 The piping manufacturer is to ensure that each item of piping is traceable to the batch or batches of material used in its manufacture. The unique identifications referred to in 4.3.4 are to be included on all documents.

4.3.10 The curing oven is to be suitable for the intended purpose and all pyrometric equipment is to be calibrated at least annually and adequate records maintained.

4.3.11 The temperature of the pipe or fitting is to be controlled and recorded by the attachment of suitably placed thermocouples.

4.4 Quality assurance

4.4.1 The piping manufacturer is to have a quality assurance system approved to ISO 9001 or equivalent. This system should ensure that the pipes and fittings are produced with uniform and consistent mechanical and physical properties in accordance with acceptable standards.

4.5 Dimensional tolerances

4.5.1 Dimensions and tolerances are to conform to the Manufacturing Specification.

4.5.2 The wall thicknesses of the pipes are to be measured at intervals around the circumference and along the length in accordance with an appropriate National Standard. The thicknesses are to accord with the Manufacturing Specification.

4.5.3 The responsibility for maintaining the required tolerances and making the necessary measurements rests with the manufacturer. Occasional checking by the Surveyor does not absolve the manufacturer from this responsibility.

4.6 Composition

4.6.1 The composition of the pipes and fittings is to be in accordance with the Manufacturing Specification.

4.6.2 Where alternative materials are used (*see* 4.2.4), the manufacturer is to demonstrate to the Surveyor's satisfaction, and prior to their introduction, their suitability with respect to the performance of the piping. Otherwise, full testing as specified in 4.7 will be required.

4.7 Testing

4.7.1 For thermoplastic pipes, the polymer manufacturer is to make the following measurements on samples taken from each batch:
(a) Melting point.
(b) Melt flow index.
(c) Density.
(d) Filler/pigment content, where applicable.
(e) Tensile stress at yield and break.
(f) Tensile strain at yield and break.

4.7.2 The values obtained are to be certified by the polymer manufacturer.

4.7.3 For reinforced thermoset pipes,the resin manufacturer is to determine, on samples taken from each batch, at least the following:
(a) All resins:
  (i) Viscosity.
  (ii) Gel time.
  (iii) Filler content, where applicable.
(b) Polyester resins:
  (i) Type (orthophthalic, isophthalic, etc.).
  (ii) Volatiles content.
  (iii) Acid value.
(c) Epoxide resins:
  (i) Free epoxide content.
(d) Phenolic resins:
  (i) Free phenol content.
  (ii) Free formaldehyde content.

4.7.4 The values obtained are to comply with the requirements of the Manufacturing Specification.

4.7.5 Where the resin manufacturer mixes batches, both the original batches and the mixed batch are to be tested in accordance with 4.7.1 to 4.7.3 as appropriate. The mixed batch is then to be given a unique batch number.

4.7.6 The polymer or resin manufacturer is to demonstrate that each batch of polymer or resin satisfies the requirement for temperature of deflection under load and this is not to be less than 80°C.

4.7.7 These measurements should be repeated on each batch by the piping manufacturer. Where this is not done, LR may require that the tests be made on a random basis by an independent laboratory.

4.7.8 The piping manufacturer is to confirm, by means of tests on at least one batch in twenty, that the temperature of deflection under load exceeds the specified minimum under manufacturing conditions.

4.7.9 Where reinforcements are used, at least the following are to be recorded, where applicable:
(a) Tex of yarn(s) or roving(s).
(b) Ends per 100 mm in all reinforcement orientations.
(c) Weight per square metre.
(d) Binder/size content.
(e) Stitch type and count.
(f) Type of fibre used.
(g) Surface treatment and/or finish.

4.7.10 All items in 4.7.9 are to comply with the Manufacturing Specification.

4.7.11 The piping manufacturer is to maintain accurate records of resin and glass usage and is to calculate the resin/glass ratio on an ongoing basis.

4.7.12 During manufacture of the piping, apart from the requirements of 4.7.5, 4.7.6 and 4.7.8, tests are to be carried out on the constituents and final product in accordance with Table 14.4.1.

4.7.13 The standards of acceptance are those listed in the Manufacturing Specification approved by LR.

Table 14.4.1 Testing during manufacture of pipes

Component/ operation	Characteristic	Rate of testing
Resin/curing agent/catalyst	Gel time Rate of consumption	Two per shift Continuous
Reinforcement	Quality Wind angle Rate of consumption	Continuous Continuous Continuous
Resin/ reinforcement	Ratio	Continuous
Pipe	Post-cure: temperature of the pipe in oven	Continuous
	Cure level	At least eight per length
	Dimensions	Each length
	Hydraulic pressure test	Each length
	Electrical resistance	Each length (*see* Note)
	Hydraulic bursting test	At Surveyor's discretion
	Axial strength	At Surveyor's discretion

NOTE
Measurements of electrical resistance are only required on piping where the operating conditions given in Pt 5, Ch 12,5.2.4 of the *Rules and Regulations of the Classification of Ships* apply.

4.7.14 At the Surveyor's discretion, sections of pipe are to be subjected to hydraulic bursting tests and/or measurements of axial strength.

4.7.15 If the batch of resin or polymer, or the curing agent, or their ratio is changed during manufacture of a batch of pipes, at least two additional measurements of the gel time are to be carried out during each shift.

4.8 Visual examination

4.8.1 All pipes and fittings are to be visually examined and are to be free from surface defects and blemishes.

4.8.2 The pipes are to be reasonably straight and the cut ends are to be square to the axis of the pipe.

4.9 Hydraulic test

4.9.1 Each length of pipe is to be tested at a hydrostatic pressure not less than 1,5 times the rated pressure of the pipe.

4.9.2 The test pressure is to be maintained for sufficient time to permit proof and inspection. Unless otherwise agreed, the manufacturer's certificate of satisfactory hydraulic test, endorsed by the Surveyor, will be accepted.

4.10 Repair procedure

4.10.1 Repairs are not allowed, with the exception of minor cosmetic blemishes as detailed in 1.10.1.

4.10.2 A repair procedure for these minor blemishes is to be included in the Manufacturing Specification.

4.11 Identification

4.11.1 All piping is to be identified in such a manner that traceability to all the component materials used in its manufacture is ensured. The Surveyor is to be given full facilities for tracing the material when required.

4.11.2 Pipes and fittings are to be permanently marked by the manufacturer by moulding, hot stamping or by any other suitable method, such as printing, in accordance with 1.11. The markings are to include:
(a) Identification number, *see* 4.11.1.
(b) LR or Lloyd's Register, and the abbreviated name of LR's local office.
(c) Manufacturer's name or trademark.
(d) Pressure rating.
(e) Design standard.
(f) Material system with which the piping is made.
(g) Maximum service temperature.

4.12 Certification

4.12.1 The manufacturer is to provide the Surveyor with copies of the test certificates or shipping statements for all material which has been accepted.

4.12.2 Each test certificate is to contain the following particulars:
(a) Purchaser's name and order number.
(b) If known, the contract number for which the piping is intended.
(c) Address to which piping is despatched.
(d) Type and specification of material.
(e) Description and dimensions.
(f) Identification number, *see* 4.11.1.
(g) Test results.

■ *Section 5* Control of material quality for composite construction

5.1 Scope

5.1.1 This Section gives the general requirements for control of material quality when used in the construction of composite craft.

5.1.2 For composite craft built under the Rules, the survey of materials is to be conducted in accordance with the requirements of Sections 1 to 3 and this Section.

5.2 Design submission

5.2.1 The requirements for design submission are detailed in the appropriate Part of the Rules which includes full information on composite materials.

5.3 Construction

5.3.1 All constructions are to be carried out using materials approved or accepted by LR.

5.3.2 All materials are to be in accordance with the approved construction documentation.

5.3.3 All batches of materials are to be provided with unique identifications by their manufacturers. Components are to be similarly identified.

5.3.4 No batch of material is to be used later than its date of expiry.

5.3.5 The Builder is to ensure that all batches of materials are used systematically and sequentially.

5.3.6 The Builder is to maintain, on a continuous basis, records of the amounts of resin and reinforcement used, in order to ensure that the proportions remain within the limits set in the construction documentation.

5.3.7 Records are to be kept of the sequence and orientation of the reinforcements.

5.3.8 The Builder is to ensure that each section of the construction is traceable to the batch or batches of material used. The unique identifications required under 1.11.1 are to be included on all relevant quality control documentation.

5.3.9 Any curing system used is to be demonstrated as suitable for the intended purpose and all pyrometric equipment is to be calibrated at least annually and adequate records maintained.

5.3.10 The post-curing temperature is to be controlled and recorded by the attachment of suitably placed thermocouples.

5.4 Quality assurance

5.4.1 Where the Builder has a quality assurance system, this is to include the requirements of this Section.

5.5 Dimensional tolerances

5.5.1 Dimensions and tolerances are to conform to the approved construction documentation.

5.5.2 The thicknesses of the laminates are, in general, to be measured at not less than ten points, evenly distributed across the surface. In the case of large sections, at least ten evenly distributed measurements are to be taken in bands across the width at maximum spacing of two metres along the length.

5.5.3 The responsibility for maintaining the required tolerances and making the necessary measurements rests with the Builder. Monitoring and random checking by the Surveyor does not absolve the Builder from this responsibility.

5.5.4 Where ultrasonic thickness gauges are used, these are to be calibrated against an identical laminate (of measured thickness) to that on which the thickness measurement is to be carried out. If suitable pieces are not available from the construction, then a small sample of identical lay-up is to be prepared.

5.6 Material composition

5.6.1 The materials, prefabricated sections or components used are to be in accordance with the approved construction documentation.

5.6.2 Where alternative materials are used, these are to be of approved or accepted types and the manufacturer is to demonstrate to the Surveyor's satisfaction, prior to their introduction, their suitability with respect to performance, otherwise full testing as appropriate will be required.

5.7 Material testing

5.7.1 Where so required, the material manufacturer is to provide the purchaser with certificates of conformity for each batch of material supplied, indicating the relevant values specified in 5.7.4 to 5.7.8. These values are to comply with those specified by the approved construction documentation.

5.7.2 Where the Builders do not conduct verification testing of the information indicated in 5.7.4 to 5.7.8, they are to ensure that copies of all certificates of conformity (which must indicate the actual tested values) are obtained for all batches of materials received, and maintain accurate records. The Surveyor may at any time select a sample of a material for testing by an independent, where applicable, source and should such tests result in the material failing to meet the specification, then that batch will be rejected.

5.7.3 The following tests are to be carried out, where applicable, on receipt of any material:

(a) The consignment is to be divided into its respective batches and each batch is to be labelled accordingly.
(b) Each batch is to be visually examined for conformity with the batch number, visual quality and date of expiry.
(c) Each batch is to be separately labelled and stored separately.
(d) Each unit, within the batch, is to be labelled with the batch number.
(e) Records are to be maintained of the above and these are to be cross-referenced with the certificate of conformity for the material and/or the Builder's own test results.

5.7.4 For thermosetting resins, reinforced or otherwise, the resin manufacturer is to have determined, on samples taken from each batch, at least the following:

(a) All resins:
  (i) Viscosity.
  (ii) Gel time.
  (iii) Filler content, where applicable.

(b) Polyester and vinylester resins:
  (i) Type (orthophthalic, isophthalic, etc.).
  (ii) Volatiles content.
  (iii) Acid value.

(c) Epoxide resins:
  (i) Free epoxide content.

(d) Phenolic resins:
  (i) Free phenol content.
  (ii) Free formaldehyde content.

5.7.5 For thermoplastics, the polymer manufacturer is to have made the following measurements on samples taken from each batch:

(a) Melting point.
(b) Melt flow index.
(c) Density.
(d) Filler/pigment content, where applicable.
(e) Tensile stress at yield and break.
(f) Tensile strain at yield and break.

5.7.6 Where the resin or polymer manufacturer mixes batches, both the original batches and the mixed batch are to be tested in accordance with 5.7.4 or 5.7.5 as appropriate. The mixed batch is then to be given a unique batch number.

5.7.7 For reinforcements, the material manufacturer is to have recorded, where applicable, the following for each batch of material:

(a) Tex of yarn(s) or roving(s).
(b) Ends per 100 mm in all reinforcement orientations.
(c) Weight per square metre.
(d) Binder/size content.
(e) Stitch type and count.
(f) Type of fibre used.
(g) Surface treatment and/or finish.

5.7.8 For core materials, the following properties are to be recorded by the manufacturer for each batch:

(a) Type of material.
(b) Density.
(c) Description (block, scrim mounted, grooved).
(d) Thickness and tolerance.
(e) Sheet/block dimensions.
(f) Surface treatment.

Together with the following mechanical properties:
In the case of rigid foams:

(g) Compressive strength (stress at maximum load) and modulus of elasticity.
(h) Core shear strength.In the case of end-grain balsa:
(j) Tensile strength (stress at maximum load).
(k) Compressive strength (stress at maximum load) and modulus of elasticity.

5.7.9 During construction, tests are to be carried out on the constituents and final product in accordance with Table 14.5.1.

5.7.10 The standards of acceptance for testing are those listed in the material manufacturer's specification, approved construction documentation or agreed quality control procedures as applicable.

5.7.11 Laminate fibre content is to be determined at the request of the Surveyor, in particular where the thickness measured does not correlate with the specified fibre content, by weight. This will, in general, result in additional reinforcement being required.

5.7.12 If the batch of resin or polymer, or the curing agent, or their ratio is changed, at least two additional measurements of the gel time are to be carried out during each shift.

Table 14.5.1 Testing during construction

Component/operation	Characteristic	Rate of testing
Resin/curing agent/catalyst	Gel time Rate of consumption	Two per shift Continuous
Reinforcement	Quality Orientation Rate of consumption	Continuous Continuous Continuous
Resin/reinforcement	Ratio	Continuous
Construction	Temperature during cure/post cure Dimensions Cure level (Barcol) against resin manufacturer's specification Laminate thickness Laminate fibre content	Continuous Continuous against approved construction documentation At least one per square metre Continuous against material usage and approved construction documentation (*see also* 5.5.2 to 5.5.4) At the Surveyor's request (*see* 5.7.11)

5.8 Visual examination

5.8.1 All constructional mouldings and any components are to be visually examined and are to be free from surface defects and blemishes.

5.9 Repair procedure

5.9.1 Repairs of minor cosmetic blemishes are permitted providing that these are brought to the attention of the Surveyor.

5.9.2 A repair procedure for these minor blemishes is to be included in the agreed quality control procedures.

5.9.3 Structural repairs are subject to individual consideration and full written details must be approved by the plan approval office prior to introduction.

5.10 Material identification

5.10.1 Records of the construction are to be kept in such a manner that traceability of all the component materials used is ensured. The Surveyor is to be given full facilities for tracing the material's origin when required.

5.10.2 Small representative samples of each batch of material are to be retained, these being suitably labelled to ensure traceability.

5.10.3 When so requested by the Surveyor, the Builder is to provide copies of all test data and/or manufacturers' certificates of conformity appertaining to any material used.

5.11 Minimum tested requirements for material approval

5.11.1 This Section provides the minimum property values required of a material for approval or acceptance by LR and are applicable to materials cured under ambient conditions.

5.11.2 **Gel coat resins**. When the cast resin is tested according to the requirements of 2.3, Table 14.5.2 gives the minimum values for the respective properties.

5.11.3 **Laminating resins**. When tested according to the requirements of 2.3 and 2.4, Tables 14.5.3 and 14.5.4 give the minimum properties for the cast resin and chopped strand mat laminate respectively.

5.11.4 When tested to the requirements of 2.4 for reinforcements, Table 14.5.5 gives the minimum properties for laminates.

5.11.5 Alternatively, materials may be approved by use of the actual tested values whereby the approval value shall equal the mean of the tested values minus twice the standard deviation of a minimum of five tested values.

Table 14.5.2 Gel coat resins, minimum property values

Properties	Minimum value
Tensile strength (stress at maximum load)	40 N/mm^2
Tensile stress at break	40 N/mm^2
Tensile strain at maximum load	2,5%
Modulus of elasticity in tension	As measured
Flexural strength (stress at maximum load)	80 N/mm^2
Modulus of elasticity in flexure	As measured
Barcol hardness	As measured at full cure
Water absorption	70 mg (max)

Table 14.5.3 Laminating resins, minimum property values

Properties	Minimum value
Tensile strength (stress at maximum load)	40 N/mm^2
Tensile stress at break	40 N/mm^2
Tensile strain at maximum load	2,0%
Modulus of elasticity in tension	As measured
Barcol hardness	As measured at full cure
Temperature of deflection under load	55°C
NOTE These minimum values are for the recommended glass content by weight of 0,3.	

5.12 Closed cell foams for core construction based on PVC or polyurethane

5.12.1 Table 14.5.6 gives minimum values for closed cell forms for core construction based on PVC or polyurethane.

5.12.2 Other types of foam will be subjected to individual consideration. A minimum core shear strength of 0,5 N/mm^2 is to be achieved.

5.13 End-grain balsa

5.13.1 Table 14.5.7 gives the minimum property requirement for end-grain balsa.

5.14 Synthetic chocking compounds

5.14.1 After 1000 hours the chocking resin must be stabilised and maximum creep is to be less than or equal to 0,2 per cent.

Table 14.5.4 Laminating resins, minimum values for properties for CSM laminate at 0,3 glass fraction by weight

Properties	Minimum value
Tensile strength (stress at maximum load)	90 N/mm^2
Secant modulus at 0,25% and 0,5% strain respectively	6,9 kN/mm^2
Compressive strength (stress at maximum load)	125 N/mm^2
Compressive modulus	6,4 kN/mm^2
Flexural strength (stress at maximum load)	160 N/mm^2
Modulus of elasticity in flexure	5,7 kN/mm^2
Apparent interlaminar shear strength (*see* Note)	18 N/mm^2
Fibre content	As measured (0,3)
Water absorption	70 mg (max)

NOTE
Applicable only to the special test for environmental control resins.

5.14.2 Compliance with 5.14.1 is to be demonstrated at the time of chocking compound approval for a specified cure/post-cure schedule. The Izod, barcol, compression, and water and oil absorption are additionally to be determined for the creep tested cure/post cure schedule.

5.14.3 Confirmation of creep, barcol and compression will be required for cure/post-cure conditions which differ from those shown on the product approval certificate.

5.15 Other materials

5.15.1 All other materials will be subject to special consideration.

Table 14.5.5 Laminates, minimum property requirements

Material type	Property	Value
Chopped strand mat	Tensile strength (stress at maximum load) (N/mm^2)	$200G_c + 30$
	Modulus of elasticity in tension (kN/mm^2)	$15G_c + 2,4$
Bi-directional reinforcement	Tensile strength (stress at maximum load) (N/mm^2)	$400G_c - 10$
	Modulus of elasticity in tension (kN/mm^2)	$30G_c - 0,5$
Uni-directional reinforcement	Tensile strength (stress at maximum load) (N/mm^2)	$1800G_c^2 - 1400G_c + 510$
	Modulus of elasticity in tension (kN/mm^2)	$130G_c^2 - 114G_c + 39$
Chopped strand mat	Flexural (stress at maximum load) (N/mm^2)	$502G_c^2 + 114,6$
	Modulus of elasticity in flexure (kN/mm^2)	$33,4G_c^2 + 2,7$
All	Flexural strength (stress at maximum load) (N/mm^2)	$502G_c^2 + 106,8$
	Modulus of elasticity in flexure (kN/mm^2)	$33,4G_c^2 + 2,2$
	Compressive strength (stress at maximum load) (N/mm^2)	$150G_c + 72$
	Compressive modulus (kN/mm^2)	$40G_c - 6$
	Interlaminar shear strength (N/mm^2)	$22 - 13,5G_c$ (min 15)
	Water absorption (mg)	70 (maximum)
	Glass content (% by weight)	As measured

NOTES
1. After water immersion, the values shall be a minimum of 75% of the above.
2. Where materials have reinforcement in more than two directions, the requirement will be subject to individual consideration dependent on the construction.
3. G_c = glass fraction by weight.

Table 14.5.6 Minimum characteristics and mechanical properties of rigid expanded foams at 20°C

Material	Apparent density kg/m^3	Strength (stress at maximum load) (N/mm^2)			Modulus of elasticity (N/mm^2)	
		Tensile	Compressive	Shear	Compressive	Shear
Polyurethane	96	0,85	0,60	0,50	17,20	8,50
Polyvinylchloride	60					

Table 14.5.7 Minimum characteristics and mechanical properties of end-grain balsa

Apparent density (kg/m^3)	Strength (stress at maximum load) (N/mm^2)					Compressive modulus of elasticity (N/mm^2)		Shear modulus of elasticity (N/mm^2)
	Compressive		Tensile		Shear	Direction of stress		
	Direction of stress							
	Parallel to grain	Perpendicular to grain	Parallel to grain	Perpendicular to grain		Parallel to grain	Perpendicular to grain	
96	5,0	0,35	9,00	0,44	1,10	2300	35,2	105
144	10,6	0,57	14,6	0,70	1,64	3900	67,8	129
176	12,8	0,68	20,5	0,80	2,00	5300	89,6	145

Rules and Regulations for the Classification of Mobile Offshore Units

Part 3
Functional Unit Types and Special Features
June 2013

LIFE MATTERS

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Section

Section 1 Rule application

1.1 General

1.1.1 This Part is applicable to all types of mobile offshore units as defined in Pt 1, Ch 2,2, including their positional mooring systems. Units of unconventional type or form will receive individual consideration based on the general standards of these Rules.

1.1.2 In addition to the Rule requirements for Classification, attention is to be given to the relevant statutory Regulations of the National Administration of the country of registration and in the area of operation, as applicable, *see* Pt 1, Ch 2,1.1.

1.1.3 In general, a unit which due to its design and function is intended to remain and operate at one location for long periods of its working life will be considered as a mobile unit in accordance with these Rules, provided the unit can be moved to a new location without carrying out major works or structural modifications. *See also* Ch 3,1.

1.1.4 Hull scantlings of surface type units are to comply with LR's *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships), but all aspects which relate to the specialised offshore function of the unit will be considered on the basis of these Rules. *See* Chapter 2 and Pt 4, Ch 4,4.

1.1.5 Lifting appliances are to comply with the requirements of LR's *Code for Lifting Appliances in a Marine Environment* (hereinafter referred to as LAME), *see also* Chapter 11.

1.1.6 The requirements stated in this Part for the particular unit types and special features class notations are supplementary to those stated in other Parts of these Rules.

Section 2 Information required

2.1 General

2.1.1 General requirements regarding information required are given in Pt 3, Ch 1,5 of the Rules for Ships, which are to be complied with as applicable.

2.1.2 Additional plans, documents and data are to be submitted for approval and information as required by the relevant Parts of these Rules together with the additional information related to the unit type and its specialised function as defined in this Part.

2.1.3 Where an **OIWS** notation for In-water Survey is to be assigned, *see* Pt 1, Ch 2, plans and information covering the following items are to be submitted as applicable:

- Details showing how rudder pintle and bush clearances are to be measured and how the security of the pintles in their sockets is to be verified with the unit afloat.
- Details and arrangements for inspecting thrusters and sea chests.
- Details showing how stern bush clearances are to be inspected and measured with the unit afloat.
- Details of arrangements for servicing and unshipping thrusters.
- Details and arrangements for servicing sea inlet valves and checking sea chests.
- Details of underwater marking, *see* Section 6.
- Details of coating systems and cathodic protection, *see* Part 8.

2.2 Construction booklet

2.2.1 A **construction booklet** including a set of plans showing the exact location and extent of application of different grades and mechanical properties of structural materials, together with welding procedures employed for primary structure, is to be submitted for approval and a copy to be placed aboard the unit. Any other relevant construction information is to be included in the booklet, including restrictions or prohibitions regarding repairs or modifications.

2.2.2 Similar information is to be provided when aluminium alloy or other materials are used in the construction of the unit.

2.2.3 Copies of the main scantlings plans and details of the corrosion control system fitted are to be placed on board the unit.

Section 3 Operations Manual

3.1 General

3.1.1 A manual of operating instructions is to be prepared and placed on board each unit and should be made readily available to all concerned in the safe operation of the unit, *see also* 3.2.4.

3.1.2 It is the responsibility of the Owner to provide in the Operations Manual all the necessary instructions and limits on the operation of the unit to ensure that the environmental and operating loading conditions on which the classification is based will not be exceeded in service.

3.1.3 Where a National Administration has a specific requirement regarding the contents of the Operations Manual, it is the responsibility of the Owner to comply with such Regulations.

3.1.4 The Operations Manual is to be submitted when the plans of the unit are being approved by LR. The Operations Manual will be reviewed and noted in respect of those aspects covered by Classification only.

3.1.5 Where a unit is modified during its service life, it is the Owner's responsibility to update the Operations Manual, as necessary, and advise LR of any changes which may affect the Classification of the installation.

3.2 Information to be included

3.2.1 In general, the Operations Manual should include the following minimum information, as applicable:

- General description and particulars of the unit.
- Chain of command and general responsibilities during all normal operating modes and emergency operations.
- Limiting design data for each approved mode of operation, including design and variable loading, draughts, air gap, wave height, wave period, wind, current, minimum sea and air temperatures, assumed sea bed conditions, orientation, and any other applicable environmental factors, such as icing.
- A description of any inherent operational limitations for each mode of operation and for each change in mode of operation. For surface type units, *see also* 3.2.4.
- Permissible deck loading plan.
- General arrangement plans showing watertight and weathertight boundaries.
- The location and type of watertight and weathertight closures, vents, air pipes, etc., and the location of down-flooding points.
- The location, type and weights of permanent ballast installed on the unit.
- A description of the signals used in the general alarm, public address, fire and gas alarm systems.
- Hydrostatic curves or equivalent data.
- A capacity plan showing the capacities and the centres of gravity of tanks and bulk material stowage spaces.
- Tank sounding tables or curves showing capacities, the centres of gravity in graduated intervals and the free surface data of each tank.
- Plans and description of the ballast system and instructions for ballasting.
- Plan indicating hazardous areas.
- Fire control and safety/evacuation plans.
- Light ship data based on the results of an inclining experiment, etc.
- Stability information in the form of maximum KG versus draught curve, or other suitable parameters, based upon compliance with the required intact and damaged stability criteria.
- Representative examples of loading conditions for each approved mode of operation, together with the means for evaluation of other loading conditions. For surface type units, *see also* 3.2.4.
- Positional mooring system and limiting conditions of operation.
- Description and limitations of any onboard computer used in operations such as ballasting, anchoring, dynamic positioning and in trim and stability calculations.
- Plan of towing arrangements and limiting conditions of operation.
- Description of the main power system and limiting conditions of operation.
- Details of emergency shut-down procedures.
- Identification of the helicopter used for the design of the helicopter deck.

3.2.2 Instructions for the operation of the unit are to include precautions to be taken in adverse weather, changing mode of operation, any inherent limitations of operations, approximate time required for meeting severe storm conditions and mooring pattern/heading.

3.2.3 For self-elevating units, the manual is to include instructions on safety during jacking-up and jacking-down of the hull and over the period of time the unit is in the elevated position, and during extreme weather conditions while in transit, including the positioning and securing of legs, cantilever drill floor structures and heavy cargo and equipment which might shift position. Limitations on the maximum permissible rigid body motions of the unit, and allowable sea states whilst elevating or lowering the legs.

3.2.4 For surface type units, sufficient information is to be supplied to the Master/Operator to enable him to arrange loading and ballasting in such a way as to avoid the creation of unacceptable stresses in the unit's structure. This information is to be provided by means of a Loading Manual and in addition, where required, by means of an approved loading instrument, *see* Pt 1, Ch 2,1. The Loading Manual may form part of the Operations Manual, or may be a separate document.

Section 4 Materials

4.1 General

4.1.1 The Requirements are intended for units to be constructed of materials manufactured and tested in accordance with the Rules. Where it is intended to use materials manufactured by different processes or having different properties, their use will be specially considered by LR.

4.1.2 Units should be constructed from steel or other suitable material having properties acceptable to LR, taking into consideration the temperature extremes in the areas in which the unit is intended to operate.

4.1.3 The materials used for the construction and repair of units and installed machinery are to be manufactured and tested in accordance with the requirements of the Rules for Materials.

4.1.4 As an alternative, materials which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of the Rules for Materials or are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of the Rules for Materials.

4.1.5 Materials for specialised areas of the unit, related to its function or special features notation, are to be in accordance with the relevant Chapters of this Part, *see also* 4.3.

4.1.6 Consideration should be given to the minimisation of hazardous substances used in the design and construction of the unit. The design and construction should facilitate recycling and removal of hazardous materials.

4.1.7 Materials which contain asbestos shall be prohibited.

4.2 Material selection

4.2.1 Materials are to be selected in accordance with the requirements of the design in respect of static strength, fatigue strength, fracture resistance and corrosion resistance, as appropriate.

4.2.2 The grades of steel to be used in the construction of the unit are to be related to the thickness of the material, the location on the unit and the minimum design temperature, *see* 4.4.

4.2.3 The grades of steel to be used for the drilling plant and the production and process plant are to be in accordance with the requirements of Chapters 7 and 8 respectively.

4.2.4 The effects of corrosion, either from the environment or from the products handled on the unit or its associated plant and machinery, are to be taken into account in the design.

4.3 Structural categories

4.3.1 The structural categories for the hull construction and the corresponding grades of steel used in the structure are to be in accordance with Pt 4, Ch 2.

4.3.2 The structural categories for supporting structures for drilling plant and production and process plant are to be in accordance with Chapters 7 and 8 respectively.

4.4 Minimum design temperature

4.4.1 The minimum design temperature is a reference temperature used as a criterion for the selection of the grade of steel to be used.

4.4.2 The minimum design air and sea temperatures for exposed structure are to be taken as the lowest daily mean temperature for the unit's proposed areas of operation based on the 50 year average return period. The temperature is to be rounded down to the nearest degree Celsius.

4.4.3 The minimum design temperature (MDT) for drilling plant and production and process plant is to be defined by the designers/Builders but when appropriate the MDT should not be higher than the MDT for the exposed structure defined in 4.4.2.

4.5 Aluminium structure, fittings and paint

4.5.1 The use of aluminium alloy is permitted for secondary structure as defined in Pt 4, Ch 2.

4.5.2 Where aluminium alloy is used for secondary structure, the material is to conform with the requirements of Chaper 8 of the Rules for Materials.

4.5.3 The use of aluminium alloy for primary structure will be specially considered.

4.5.4 Where aluminium alloy is used in the construction of fire divisions, it is to be suitably insulated in accordance with the requirements of the appropriate National Administration, *see* 1.1.2.

4.5.5 Since aluminium alloys may, under certain circumstances, give rise to incendive sparking on impact with steel, the following requirements are to be complied with:

(a) Aluminium fittings in tanks used for the storage of oil and in cofferdams and pump-rooms in oil storage units are to be avoided wherever possible.
(b) Where fitted, aluminium fittings, anodes and supports in tanks used for the storage of oil, cofferdams and pump-rooms are to satisfy the requirements specified in Pt 8, Ch 2,5 for aluminium anodes.
(c) The danger of mistaking aluminium anodes for zinc anodes must be emphasised. This gives rise to increased hazard if aluminium anodes are inadvertently fitted in unsuitable locations.

(d) The underside of heavy portable aluminium structures such as gangways, etc., is to be protected by means of hard plastic or wood cover in order to avoid the creation of smears when dragged or rubbed across steel, which, if subsequently struck, may create an incendive spark. It is recommended that such protection be permanently and securely attached to the structures.

(e) Aluminium is not to be used in hazardous areas on drilling units and production and oil storage units unless adequately protected, and full details submitted for approval. Aluminium is not to be used for hatch covers to any openings to oil storage tanks.

4.5.6 For permissible locations of aluminium anodes, *see* Pt 8, Ch 2,5.

4.5.7 The use of aluminium paint is to comply with the requirements of Pt 8, Ch 3,1.

■ *Section 5* Corrosion control

5.1 General

5.1.1 The corrosion control of steelwork is to be in accordance with Part 8. The corrosion protection of mooring systems is to comply with Chapter 10.

5.1.2 The basic Rule scantlings of the external submerged steel structure of units which are derived from Pt 4, Ch 5 assume that appropriate coatings and an external cathodic protection system will be fitted. If the corrosion protection system of the submerged structure is not in accordance with the Rules the scantlings are to be suitably increased.

5.1.3 Surface type units with hull scantlings derived from LR's Rules for Ships which are assigned an **OIWS** notation are to be fitted with external cathodic protection and external coating systems in accordance with Part 8.

■ *Section 6* Underwater marking

6.1 General

6.1.1 Where an **OIWS** notation for In-water Survey is to be assigned, *see* Pt 1, Ch 2, the requirements of this Section are to be complied with.

6.1.2 The underwater structure of a unit intended to be surveyed on an in-water basis should have its main frames, bulkheads and joints, etc., clearly identified by suitable marking. Details are to be submitted for approval.

6.1.3 Marking should consist of raised lines, numerals and letters. In general, marking by welding is not to be used on surface type units.

6.1.4 If marking is to be carried out by welding, the welds should be made with continuous runs and the quality of the workmanship should be to an equivalent standard as the main hull structure. Substantial runs should be laid, continuously, using large diameter electrodes and avoiding light runs as these are more likely to promote cracking. Sharp corners in the letters are to be avoided. Marking by welding is not permitted in highly stressed areas or over existing butts or seams. The welding procedures and consumables are to be submitted for approval.

6.1.5 On steel of Grade D or E or on higher tensile steel, low hydrogen electrodes should be used, of a grade suitable for the steel. In the case of higher tensile steel, *see* Ch 3,3 of the Rules for Materials, pre-heating to about 100°C should be adopted.

6.2 Physical features

6.2.1 The following physical features are to be incorporated into the unit's design in order to facilitate the underwater inspection. When verified, they will be noted in the unit's Classification for reference at subsequent surveys.

6.2.2 **Stern bearing**. For self-propelled units, means are to be provided for ascertaining that the seal assembly on oil lubricated bearings is intact and for verifying that the clearance or weardown of the stern bearing is not excessive. For oil-lubricated bearings, this may only require accurate oil-loss-rate records and a check of the oil for contamination by sea-water or white metal. For wood or rubber bearings, an opening in the top of the rope guard and a suitable gauge or wedge would be sufficient for checking the clearance by a diver. For oil-lubricated metal stern bearings, weardown may be checked by external measurements between an exposed part of the seal unit and the stern tube bossing, or by use of the unit's weardown gauge, where the gauge wells are located outboard of the seals, or the unit can be tipped. For use of the weardown gauges, up-to-date records of the base depths are to be maintained on board. Whenever the stainless steel seal sleeve is renewed or machined, the base readings for the weardown gauge are to be re-established and noted in the unit's records and in the survey report.

6.2.3 **Rudder bearings**. For self-propelled units with rudders, means and access are to be provided for determining the condition and clearance of the rudder bearings, and for verifying that all parts of the pintle and gudgeon assemblies are intact and secure. This may require bolted access plates and a measuring arrangement.

6.2.4 **Sea suctions**. Means are to be provided to enable the diver to confirm that the sea suction openings are clear. Hinged sea suction grids would facilitate this operation.

6.2.5 **Sea valves**. For the Dry-docking Survey (Underwater Inspection) associated with the Special Survey, means must be provided to examine any sea valve.

6.2.6 Alternative arrangements to facilitate In-water Surveys will be considered; details are to be submitted to LR for approval.

■ *Section 7*
Permanent means of access

7.1 General

7.1.1 Each space within the unit should be provided with at least one permanent means of access to enable, throughout the life of a unit, overall and close-up inspections and thickness measurements of the unit's structures to be carried out by LR, the company, and the unit's personnel and others, as necessary. Such means of access should comply with the provisions of MODU Code 2009, paragraph 2.2 and with the Technical provisions for means of access for inspections, adopted by the Maritime Safety Committee by Resolution MSC.133(76), as may be amended by the IMO.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter apply to all drilling units engaged in drilling operations for the exploration and exploitation of petroleum, gas or other resources beneath the sea bed.

1.1.2 Surface type units are to comply with this Chapter, but reference should also be made to Pt 4, Ch 4,4.

1.1.3 Units engaged in rock drilling or other similar work operations not related to petroleum or gas resources will be specially considered but should comply with the general requirements of this Chapter as applicable to the unit.

1.2 Class notations

1.2.1 The Regulations for classification and the assignment of class notations are given in Pt 1, Ch 2, to which reference should be made.

1.2.2 In general, units complying with the requirements of this Chapter and the relevant Parts of the Rules will be eligible for the assignment of one of the following class type notations:

Mobile drilling unit; or

Drilling ship.

Other type notations may be assigned when considered appropriate by the Classification Committee.

1.2.3 Drilling units with an installed drilling plant facility which comply with the requirements of Chapter 7 will be eligible for the assignment of the special features class notation **DRILL**.

1.2.4 When a **DRILL** notation is not assigned to a unit with a drilling plant facility, classification of the unit will be subject to the drilling plant being certified by LR, or by another acceptable organisation.

1.2.5 When, at the request of an Owner, a unit is to be verified in accordance with the Regulations of a National Administration, a descriptive note will be included in the ClassDirect Live website.

1.3 Scope

1.3.1 The following additional topics applicable to the class type notation are covered by this Chapter:

- Structural arrangements of the unit related to drilling operations.
- Supporting structures for drilling equipment, bulk storage and raw water towers.
- Drill floor and derrick substructure.
- Drilling cantilevers.
- Structural arrangements in way of drilling wells.
- Structural mud tanks or pits.
- Deckhouses and modules related to drilling operations.
- Pipe racks and supports.
- Hazardous areas and ventilation.
- Pollution prevention.

1.4 Installation layout and safety

1.4.1 In principle, drilling units are to be divided into main functional areas to ensure that the following areas are separated and protected from each other:

(a) Drilling area:
  - Drill floor area
  - Mud circulation and treatment area.

(b) Auxiliary equipment area.

(c) Living quarters' area.

1.4.2 Attention is to be given to the relevant Statutory Regulations for fire safety of the National Administration in the country of registration and the areas of operation as applicable, *see* Pt 1, Ch 2,1 and Pt 7, Ch 3.

1.4.3 Additional requirements for safety systems and hazardous areas are given in Part 7.

1.4.4 Living quarters, lifeboats and other evacuation equipment are to be located in non-hazardous areas and be protected and separated from the drilling area.

1.5 Plans and data submission

1.5.1 Plans, calculations and data are to be submitted as required by the relevant Parts of the Rules together with the additional plans and information listed in this Chapter.

Section 2 Structure

2.1 Plans and data submission

2.1.1 In addition to the structural plans and information, as required by Ch 1,2 and Pt 4, Ch 1, the following additional plans and information are to be submitted:

- General arrangement plans.
- General arrangement plans of drilling derrick and equipment.
- Structural plans of drill floor, drilling derrick supports, substructure, drilling equipment supports, pipe rack and supports.
- Structural arrangements in way of drilling wells.
- Moveable drilling cantilevers and skid beams.
- Hull supporting structures.
- Hull structural plans of mud compartments, mud tanks and pump-rooms.
- Deckhouses and modules.

2.2 General

2.2.1 The general hull strength is to comply with the requirements of Part 4 taking into account the drilling structures and applied equipment weights and forces introduced by the drilling operations. Attention should be paid to loads resulting from hull flexural effects at support points. For surface type units, *see also* Ch 1,1.

2.2.2 The design loadings for the strength of the drill floor and substructure are to be defined by the designers/Builders and calculations are to be submitted.

2.2.3 Strength calculations are to be submitted for moveable drilling cantilevers, skid beams and their supports. The clearances between the cantilever support claw and the skidding guides is the responsibility of the designers/Builders.

2.2.4 The maximum reaction forces from the drilling derrick are to be determined from an acceptable National Code or Standard and should take into account the load effects from vessel motions, the drillpipe setback, hook load, rotary table and tensioning equipment, *see* Chapter 7.

2.2.5 When the unit is to operate in an area which could result in the build-up of ice on the drilling derrick and other structures, the effects of ice loading is to be included in the calculations, *see* Pt 4, Ch 3,4.

2.2.6 The local structure should be reinforced for the component forces from drilling equipment and tensioner forces, and the design loadings are to be determined in accordance with Chapter 7.

2.2.7 The supporting structure and attachments under large equipment items are also to be designed for the emergency condition as defined in Ch 8,1.4.

2.2.8 Attention should be paid to the capability of support structures to withstand buckling, *see* Pt 4, Ch 5,4.

2.2.9 When blast walls are fitted on the unit, the primary supporting structure in way of the blast walls is to be designed for the maximum design blast force with the permissible stress levels in accordance with Pt 4, Ch 5,2.1.1(c).

2.3 Well structure

2.3.1 The primary hull strength of the unit is to be maintained in way of drilling wells and other large deck openings and suitable compensation is to be fitted as necessary. For surface type units the minimum hull modulus in way of the drilling well is to satisfy the Rule requirements for longitudinal strength.

2.3.2 Arrangements are to be made to ensure continuity of strength at the ends of longitudinal and well side bulkheads. In general, the design should be such that the bulkheads are connected to bottom and deck girders by means of large, suitably shaped brackets arranged to give a good stress flow at their junctions with both the girders and bulkheads.

2.3.3 The boundary bulkheads of drilling wells are to be designed for the maximum forces imposed by the drilling operations. The minimum scantlings of well bulkheads are to comply with the requirements for tank bulkheads in Pt 4, Ch 6,7 using the load head measured to the top of the well, but in no case is the well plating to have a thickness less than 9,0 mm.

2.4 Permissible stresses

2.4.1 In general, the permissible stresses in the structure in operating, transit and survival conditions are to comply with Pt 4, Ch 5,2 but the minimum scantlings of the local structure are to comply with Pt 4, Ch 6. For surface type units, *see also* Pt 4, Ch 4,4.

2.4.2 Permissible stresses for lattice type structures may be determined from an acceptable code, *see* Part 3, Appendix A.

2.5 Mud tanks

2.5.1 The scantlings of structural mud tanks are not to be less than those required for tanks in Pt 4, Ch 6,7 using the design density of the mud. In no case is the relative density of wet mud to be taken less than 2,2 unless otherwise agreed with LR.

2.5.2 Divisions in mud tanks or pits are to be designed for one-sided loading and the scantlings are to comply with the requirements for tanks in Pt 4, Ch 6,7.

2.6 Deckhouses and modules

2.6.1 The scantlings of structural deckhouses are to comply with Pt 4, Ch 6,9. Where deckhouses support equipment loads they are to be suitably reinforced.

2.6.2 The strength of containerised modules which do not form part of the main hull structure will be specially considered in association with the design loadings.

2.6.3 When containerised modules can be subjected to wave loading the scantlings are not to be less than required by 2.6.1.

2.7 Pipe racks

2.7.1 The pipe rack is to be designed for the following normal operating loads as applicable:

- Gravity loads.
- Maximum dynamic loads due to wave-induced unit motions.
- Direct wind loads.
- Ice and snow loads.

2.7.2 The pipe rack supports are also to be designed for an emergency condition as defined in Ch 8,1.4.

2.7.3 In general, the pipe rack supports are to be aligned with the primary under-deck structure. Where this is not practicable additional under-deck supports are to be fitted. Deck girders and under-deck supports are to comply with Pt 4, Ch 6,4.

2.7.4 In the emergency condition arrangements are to be made to restrain the pipes in their stowed position and details are to be submitted for approval.

2.8 Bulk storage vessels

2.8.1 Free standing bulk storage vessels are to comply with the requirements of Ch 8,4.

2.8.2 The deck supports under free standing bulk storage vessels are to comply with the requirements for local structure in Pt 4, Ch 6, taking into account the maximum design reaction forces.

2.8.3 Where bulk storage vessels penetrate watertight decks and can be subjected to external hydrostatic pressure due to progressive flooding in hull damage conditions, the bulk storage vessel is to be suitably reinforced and the permissible stress is not to exceed the code stress in accordance with Ch 8,4.

2.9 Watertight and weathertight integrity

2.9.1 The general requirements for watertight and weathertight integrity are to be in accordance with Pt 4, Ch 7.

2.9.2 The integrity of the weather deck is to be maintained. Where items of plant equipment penetrate the weather deck and are intended to constitute the structural barrier to prevent the ingress of water to spaces below the deck, their structural strength is to be equivalent to the Rule requirements for this purpose. Otherwise such items are to be enclosed in superstructures or deckhouses fully complying with the Rules. Full details are to be submitted for approval.

2.9.3 Where items of plant equipment or pipes penetrate watertight boundaries, the watertight integrity is to be maintained and full details are to be submitted for approval.

2.9.4 Where free-standing bulk storage vessels penetrate watertight decks or flats the arrangements to ensure watertight integrity will be specially considered, *see* 2.8.3.

■ *Section 3*
Hazardous areas and ventilation

3.1 Hazardous areas and ventilation

3.1.1 For the application of hazardous area classification and ventilation requirements for drilling units, *see* Pt 7, Ch 2.

3.1.2 Ventilation in the vicinity of the mud tanks is to be specially considered to ensure adequate dilution of any dangerous gases.

3.1.3 For units using oil-based mud, the tanks are to be provided with special ventilating arrangements, and for open systems the maximum oil density in the air above the tanks is not to exceed 5 mg/m^3. Ventilation of the enclosed spaces with open active mud tanks or pits is to be arranged for at least 30 air changes per hour for personnel comfort.

■ *Section 4*
Pollution prevention

4.1 General

4.1.1 When oil is added to the drilling mud, provision is to be made to limit the spread of oil on the unit, and to prevent the discharge of oil or oily residues into the sea by the provision of de-oilers and suitably alarmed oil monitoring devices.

4.1.2 Drilling bell nipples, flow lines, ditches, shale shakers, mud rooms and mud tanks and pumps are to be designed for maximum volume throughput without spillage. Equipment requiring maintenance is to have adequate spillage catchment arrangements.

4.1.3 Pollution prevention arrangements should be such that the unit can comply with the requirements of the relevant National Administrations in the country of registration and in the area of operation, as applicable.

■ *Section 1* General

1.1 Application

1.1.1 In general, the requirements of this Chapter apply to mobile units engaged in production and/or crude oil bulk storage and off-loading in offshore locations. Production units have specialised structures and plant installed on board for production and/or processing crude oil or gas. In general, oil storage units have integral tanks for the storage of crude oil in bulk and the Rules are primarily intended for units which are to store flammable liquids having a flash point not exceeding 60°C (closed-cup test). Units with bulk storage tanks for liquefied gases or liquid chemicals will be specially considered, *see* 1.1.3 and 1.1.4.

1.1.2 Surface type units which operate at a fixed geographical location are not considered as Mobile Offshore Units and are to comply with LR's *Rules and Regulations for the Classification of a Floating Offshore Installation at a Fixed Location*.

1.1.3 Units required for the storage of liquefied gas in bulk are also to comply with LR's *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquefied Gases in Bulk* (hereinafter referred to as Rules for Liquefied Gases).

1.1.4 Units required for the storage of liquid chemicals in bulk are also to comply with LR's *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquid Chemicals in Bulk* (hereinafter referred to as Rules for Liquid Chemicals).

1.2 Class notations

1.2.1 The Regulations for classification and the assignment of class notations are given in Pt 1, Ch 2, to which reference should be made.

1.2.2 In general, units complying with the requirements of this Chapter and the relevant Parts of the Rules will be eligible for the assignment of one of the following class type notations:

- Production unit.
- Floating production unit.
- Floating production and oil storage unit.
- Oil storage unit.

Other type notations may be assigned when considered appropriate by the Classification Committee.

1.2.3 Type class notations for units with bulk storage tanks for liquefied gases or liquid chemicals will be specially considered by the Classification Committee.

1.2.4 When, at the request of the Owner, a unit is to be verified in accordance with the Regulations of a National Administration, a descriptive note will be included in the ClassDirect Live website, *see* Pt 1, Ch 2,7.

1.2.5 Production units with an installed process plant facility, which comply with the requirements of Chapter 8, will be eligible for the assignment of the special features class notation **PPF**. For units with riser systems, *see also* Chapter 12.

1.2.6 When a **PPF** notation is not assigned to a unit with a process plant facility, classification of the unit will be subject to the process plant being certified by LR, or by another acceptable organisation.

1.2.7 Production units without an installed process plant facility are to comply with the general requirements of Chapter 8 as applicable.

1.2.8 Units with an installed drilling plant facility, which comply with the requirements of Chapter 7, will be eligible for the assignment of the special features class notation **DRILL**.

1.2.9 When a **DRILL** notation is not assigned to a unit with a drilling plant facility, classification of the unit will be subject to the drilling plant being certified by LR, or by another acceptable organisation.

1.3 Scope

1.3.1 The following additional topics applicable to the class type notation are covered by this Chapter:

- General arrangement.
- Structural arrangement of the unit.
- Supporting structures below production and process plant equipment, flare structures, and marine risers.
- Deckhouses and modules related to production operations.
- Loading of hot oils.
- Structural arrangement of oil storage tanks, cofferdams and pump-rooms.
- Access arrangements.
- Compartment minimum thickness.
- Hazardous areas and ventilation.
- Pollution prevention.

1.3.2 Where the unit is fitted with drilling equipment, the requirements of Chapter 2 are to be complied with.

1.4 Installation layout and safety

1.4.1 In principle, production units are to be divided into main functional areas to ensure that the following areas as applicable are separated and protected from each other:

(a) Production area:
- Wellhead area.
- Processing area.

(b) Drilling area:
- Drill floor area.
- Mud circulation and treatment area.

(c) Auxiliary equipment area.

(d) Living quarters' area.

1.4.2 Attention is to be given to the relevant Statutory Regulations for fire safety of the National Administrations in the country of registration and/or in the area of operation as applicable, *see* Pt 1, Ch 2,1 and Pt 7, Ch 3.

1.4.3 Additional requirements for safety systems and hazardous areas are given in Part 7.

1.4.4 Living quarters, lifeboats and other evacuation equipment are to be located in non-hazardous areas and be protected and separated from production and wellhead areas.

1.4.5 In general, production units with crude oil bulk storage tanks are to be designed so that the arrangement and separation of living quarters, storage tanks, machinery rooms, etc., are arranged in accordance with the *International Convention for the Safety of Life at Sea 1974* as amended, Regulations 11-2/56. Where this is not practicable owing to the unconventional design construction of the unit, special consideration will be given to other arrangements which provide equivalent separation and protection. *See also* Pt 1, Ch 2,1.1.11. For surface type units with crude oil bulk storage tanks, the general arrangement and separation of spaces are to comply with Pt 4, Ch 9 of the Rules for Ships, or equivalent arrangements provided.

1.4.6 The position of the process plant in relation to storage tanks for crude oil, gas or other products will be specially considered, and consideration will be given to the requirements with regard to the provision of effective separation, methods of storage, loading and discharging arrangements.

1.4.7 Provision is to be made for purging, gas freeing, inerting or otherwise rendering safe crude oil bulk storage tanks, process plant and process storage facilities before the unit moves to a new location.

1.5 Plans and data submission

1.5.1 Plans, calculations and data are to be submitted as required by the relevant Parts of the Rules together with the additional plans and information listed in this Chapter.

■ *Section 2* **Structure**

2.1 Plans and data submission

2.1.1 In addition to the structural plans and information as required by Ch 1,2 and Pt 4, Ch 1 the following additional plans and information are to be submitted:
- General arrangement.
- General arrangement plans of the production plant and process equipment layout.
- Structural supports below plant equipment.
- Structural plans of crude oil tanks, ballast tanks, coffer-dams, void spaces, pump-rooms and machinery spaces.
- Deckhouses and modules.

2.1.2 When the unit is fitted with drilling equipment, the additional plans required by Ch 2,2 are to be submitted as applicable.

2.2 General

2.2.1 The general hull strength is to comply with the requirements of Part 4, taking into account the type of unit, the imposed equipment weights and forces from the production and process plant, mooring forces and drilling plant, when fitted. Attention should be paid to loads resulting from hull flexural effects at support points.

2.2.2 The supporting structure below equipment is to be designed for all operating conditions and the maximum design loadings from the production and process plant imposed on the structure are to be determined in accordance with Chapter 8.

2.2.3 Decks and other under-deck structure supporting the plant are to be suitable for the local loads at plant support points and an agreed uniformly distributed load acting on the deck, *see* Pt 4, Ch 6,2. The structure in way of marine risers is to be suitably reinforced for the imposed loads.

2.2.4 In general, all seatings, platform decks, girders and pillars supporting plant items are to be arranged to align with the main hull structure, which is to be suitably reinforced, where necessary, to carry the appropriate loads. Attention should be paid to the capability of support structures to withstand buckling, *see* Pt 4, Ch 5,4.

2.2.5 The strength of the unit in way of openings is to be maintained. Structure in way of openings of unusual size, configuration and/or shape may require investigation by structural analysis when requested by LR.

2.2.6 Insert plates of adequate thickness and steel grade, appropriate to the stress concentrations and locations, may be required in way of openings and structural discontinuities in primary structure.

2.2.7 Critical joints depending upon transmission of tensile stresses through the thickness of the plating of one of the members (which may result in lamellar tearing) are to be avoided wherever possible. Where unavoidable, plate material with suitable through-thickness properties will be required, *see* Ch 3,8 of the Rules for Materials and Pt 4, Ch 2,4.1.3.

2.2.8 When blast walls are fitted on the unit, the primary supporting structure in way of the blast walls is to be designed for the maximum design blast force with the permissible stress levels in accordance with Pt 4, Ch 5,2.1.1(c).

2.3 Drilling structures

2.3.1 When a unit is fitted with a drilling derrick, the requirements of Ch 2,2 are to be complied with, as applicable.

2.3.2 The design loadings for the strength of the drill floor and substructure are to be defined by the designer/Builders and calculations are to be submitted.

2.4 Permissible stresses

2.4.1 In general, the permissible stresses in the structure in operating, transit and survival conditions are to comply with Pt 4, Ch 5,2 but the minimum scantlings of the local structure are to comply with Pt 4, Ch 6. For surface type units, *see also* Pt 4. Ch 4.

2.4.2 Permissible stresses for lattice type structures may be determined for an acceptable Code, *see* Appendix A.

2.5 Well structure

2.5.1 The primary hull strength of the unit is to be maintained in way of moonpools, turret openings, drilling wells and other large deck openings and suitable compensation is to be fitted, as necessary. For surface type units, the continuity of longitudinal material is to be maintained, as far as is practicable, in way of openings and wells and the minimum hull modulus is to satisfy the Rule requirements for longitudinal strength.

2.5.2 Arrangements are to be made to ensure continuity of strength at the ends of moonpools and well side bulkheads. In general, the design should be such that the bulkheads are connected to bottom and deck girders by means of large, suitably shaped brackets arranged to give a good stress flow at their junctions with both the girders and bulkheads.

2.5.3 The boundary bulkheads of moonpools and drilling wells are to be designed for the maximum forces imposed on the structure, *see* Pt 4, Ch 4,4.

2.6 Mud tanks

2.6.1 The scantlings of structural mud tanks are not to be less than those required for tanks in Pt 4, Ch 6,7 using the design density of the mud. In no case is the relative density of wet mud to be taken less than 2,2 unless agreed otherwise with LR.

2.6.2 Divisions in mud tanks or pits are to be designed for one-sided loading and the scantlings are to comply with the requirements for tanks in Pt 4, Ch 6,7.

2.7 Deckhouses and modules

2.7.1 The scantlings of structural deckhouses are to comply with Pt 4, Ch 6,9. Where deckhouses support equipment loads, they are to be suitably reinforced.

2.7.2 The strength of containerised modules, which do not form part of the main hull structure, will be specially considered in association with the design loadings.

2.7.3 When containerised modules can be subjected to wave loading, the scantlings are not to be less than required by 2.7.1.

2.8 Pipe racks

2.8.1 The pipe rack is to be designed for the following normal operating loads as applicable:
- Gravity loads.
- Maximum dynamic loads due to wave induced unit motions.
- Direct wind loads.
- Ice and snow loads.
- Hull flexure due to hull girder bending

2.8.2 The pipe rack supports are also to be designed for an emergency condition, as defined in Ch 8,1.4.

2.8.3 In general, the pipe rack supports are to be aligned with the primary under-deck structure. Where this is not practicable, additional under-deck supports are to be fitted. Deck girders and under-deck supports are to comply with Pt 4, Ch 6,4.

2.8.4 In the emergency condition, arrangements are to be made to restrain the pipes in their stowed position and details are to be submitted for approval.

2.9 Bulk storage vessels

2.9.1 Free-standing bulk storage vessels are to comply with the requirements of Ch 8,4.

2.9.2 The deck supports under free-standing bulk storage vessels are to comply with the requirements for local structure in Pt 4, Ch 6 taking into account the maximum design reaction forces.

2.9.3 Where bulk storage vessels penetrate watertight decks and can be subjected to external hydrostatic pressure due to progressive flooding in hull damage conditions, the bulk storage vessel is to be suitably reinforced and the permissible stress is not to exceed the Code stress in accordance with Ch 8,4.

2.10 Watertight and weathertight integrity

2.10.1 The general requirements for watertight and weathertight integrity are to be in accordance with Pt 4, Ch 7.

2.10.2 The integrity of the weather deck is to be maintained. Where items of plant equipment penetrate the weather deck and are intended to constitute the structural barrier to prevent the ingress of water to spaces below the deck, their structural strength is to be equivalent to the Rule requirements for this purpose. Otherwise such items are to be enclosed in superstructures or deckhouses fully complying with the Rules. Full details are to be submitted for approval.

2.10.3 Where items of plant equipment or pipes penetrate watertight boundaries, the watertight integrity is to be maintained and full details are to be submitted for approval. Free flooding pipes, which penetrate shell boundaries, are to have a wall thickness not less than the adjacent shell plating.

2.10.4 Where bulk storage vessels penetrate watertight decks or flats, the arrangements to ensure watertight integrity will be specially considered, *see* 2.9.3.

2.11 Access arrangements and closing appliances

2.11.1 For requirements in respect of coamings and closing of deck openings, *see* Pt 4, Ch 7,6.

2.11.2 The access arrangements on surface type units are to comply with 2.12. For other unit types, the general requirements of 2.12 are to be complied with, as applicable.

2.11.3 Ladders and platforms in tanks, pump-rooms, cofferdams, access trunks and void spaces are to be securely fastened to the structure.

2.12 Access to spaces in the oil storage area

2.12.1 Access arrangements to tanks for the storage of oil in bulk and adjacent spaces, including cofferdams, voids, vertical wing and double bottom ballast tanks, is to be direct from the open deck and such as to ensure their complete inspection.

2.12.2 In column-stabilised units where access from the open deck is not practicable, access to oil storage tanks and adjacent spaces is to be from trunks which are mechanically ventilated in accordance with Section 3. Every space is to be provided with a separate access without passing through adjacent spaces.

2.12.3 Access to double bottom tanks in way of oil storage tanks, where wing ballast tanks are omitted, is to be provided by trunks from the exposed deck led down the bulkhead. Alternative proposals will, however, be considered, provided the integrity of the inner bottom is maintained.

2.12.4 Access to double bottom spaces may also be through a cargo pump-room, pump-room, deep cofferdam, pipe tunnel or similar compartments, subject to consideration of ventilation aspects.

2.12.5 Where a duct keel or pipe tunnel is fitted, and access is normally required for operational purposes, access is to be provided at each end and at least one other location at approximately mid-length. Access is to be directly from the exposed deck. Where an after access is to be provided from the pump-room to the duct keel, the access manhole from the pump-room to the duct keel is to be provided with an oiltight cover plate. Mechanical ventilation is to be provided and such spaces are to be adequately ventilated prior to entry. A notice board is to be fitted at each entrance to the pipe tunnel stating that before any attempt is made to enter, the ventilating fan must have been in operation for an adequate period. In addition, the atmosphere in the tunnel is to be sampled by a reliable gas monitor, and where an inert gas system is fitted in cargo tanks, an oxygen monitor is to be provided.

2.12.6 Every double bottom space is to be provided with separate access without passing through other neighbouring double bottom spaces.

2.12.7 Where the tanks are of confined or cellular construction, two separate means of access from the weather deck are to be provided, one to be provided at either end of the tank space.

2.12.8 For access through horizontal openings, hatches or manholes, the dimensions are to be sufficient to allow a person wearing a self-contained air-breathing apparatus and protective equipment to ascend or descend any ladder without obstruction and also to provide a clear opening to facilitate the hoisting of an injured person from the bottom of the space. The minimum clear opening is to be not less than 600 mm x 600 mm.

2.12.9 Where practicable, at least one horizontal access opening of 600 mm x 800 mm clear opening is to be fitted in each horizontal girder in all spaces and weather deck to assist in rescue operations.

2.12.10 For access through vertical openings, or manholes providing passage through the length and breadth of the space, the minimum clear opening is to be not less than 600 mm x 800 mm at a height of not more than 600 mm from the bottom shell plating, unless gratings or other footholds are provided.

2.12.11 In double hull construction where the wing ballast tanks have restricted access through the vertical transverse webs, permanent arrangements are to be provided within the space to permit access for inspection at all heights in each bay. These arrangements, which should comprise fixed platforms, or other means, are to provide sufficiently close access to carry out Close-Up Surveys, as defined in Pt 1, Ch 3, using limited portable equipment where appropriate. Details of these arrangements are to be submitted for approval.

2.12.12 On units with very large oil storage tanks, it is recommended that consideration be given to providing permanent facilities for staging the interior of tanks situated within the oil storage region and of large tanks elsewhere. Suitable provisions would be:

- Staging which can be carried on board and utilised in any tank, including power-operated lift or platform systems.
- Enlargement of structural members to form permanent, safe platforms, e.g., bulkhead longitudinals widened to form stringers (in association with manholes through primary members).
- Provision of inspection/rest platforms at intervals down the length of access ladders.
- Provision of manholes in upper deck for access to staging in cargo tanks.

2.13 Access hatchways to oil storage tanks

2.13.1 The general requirements of Pt 4, Ch 7,6 are to be complied with.

2.14 Loading of hot oil in storage tanks

2.14.1 Hot oil may be loaded in oil storage tanks at the temperatures given below, without the need for temperature distribution and thermal stress calculations, provided the following temperatures are not exceeded during operations:

(a) 65°C for sea temperatures of 0°C and below;
(b) 75°C for sea temperatures of 5°C and above; and
(c) by linear interpolation between (a) and (b) above, for sea temperatures between 0°C and 5°C.

2.14.2 Where the stored oil is to be loaded or heated to higher temperatures than those specified in 2.14.1 before unloading, temperature distribution investigations and thermal stress calculations may be required. For surface type units, *see* Pt 4, Ch 9,12 of the Rules for Ships.

2.15 Compartment minimum thickness

2.15.1 On semi-submersible units, within the oil storage tank region in oil storage units including wing ballast tanks and cofferdams at the ends of or between oil storage tanks, the thickness of primary member webs and face plates, hull envelope and bulkhead plating is to be not less than 7,5mm.

2.15.2 Pump-rooms and other adjacent compartments are also to comply with 2.15.1.

2.15.3 The minimum compartment thickness in deep draught caisson units and buoys will be specially considered but is not to be less than 7,5 mm.

2.15.4 The compartment minimum thickness in surface type units is to comply with Pt 4, Ch 9,10 of the Rules for Ships, but turret areas are to comply with 2.15.1.

■ *Section 3*
Hazardous areas and ventilation

3.1 General

3.1.1 For the application of hazardous area classification and related ventilation requirements, *see* Pt 7, Ch 2.

3.1.2 Adequate ventilation is to be provided for all areas and enclosed compartments associated with the oil storage production and process plant. The capacities of the ventilation systems are to comply, where applicable, with the requirements of Pt 7, Ch 2,6, or to an acceptable Code or Standard adapted to suit the marine environment and taking into account any additional requirements which may be necessary during start-up of the plant.

3.1.3 Ventilation in the vicinity of mud tanks is to be specially considered to ensure adequate dilution of any dangerous gases.

3.1.4 For units using oil-based mud, the tanks are to be provided with special ventilation arrangements, and for open systems, the maximum oil density in the air above the tanks is not to exceed 5 mg/m^3. Ventilation of the enclosed spaces with open active mud tanks or pits is to be arranged for at least 30 air changes per hour for personnel comfort.

■ *Section 4*
Pollution prevention

4.1 General

4.1.1 Sumps and savealls are to be provided at potential spillage points, and drainage systems are to have adequate capacity and be designed for ease of cleaning.

4.1.2 Production manifolds are to be located and installed so that in the event of leakage in an enclosed area, a leakage detection and shut-down system will be activated. In open areas, arrangements are to be such that oil spillage will be contained, and that suitable drainage and recovery provisions are made.

4.1.3 Maintenance of production and process systems and equipment is to be governed by a permit-to-work system with rigid control on spillage prevention when opening up or testing is being carried out.

4.1.4 The arrangements for the onboard storage, and the disposal, of bilge and effluent from the production and process plant areas and spaces are to be submitted for consideration.

4.1.5 Oily water treatment systems are to have sufficient capacity for treatment of bilge and effluent water from the production and process plant areas and spaces.

4.1.6 When oil is added to the drilling mud, provision is to be made to limit the spread of oil on the unit, and to prevent the discharge of oil and oily residue into the sea by the provision of de-oilers and suitably alarmed oil monitoring devices.

4.1.7 Drilling bell nipples, flow lines, ditches, shale shakers, mud rooms and mud tanks and pumps are to be designed for maximum volume throughput without spillage. Equipment requiring maintenance is to have adequate spillage catchment arrangements.

4.1.8 Pollution prevention arrangements are to be such that the unit can comply with the requirements of the relevant National Administrations in the country of registration and in the areas of operation as applicable.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter apply to accommodation and offshore support units as defined in Pt 1, Ch 2,2 whose primary function is to provide support services to offshore installations. Self-elevating accommodation units which are unmanned in transit conditions need not comply with Section 3.

1.1.2 The requirements in this Chapter are supplementary to those given in the relevant Parts of the Rules.

1.1.3 The requirements for fire-fighting units are given in Chapter 5.

1.1.4 Support vessels which have a diving complex on board are to have the diving installation approved in accordance with LR's *Rules and Regulations for the Construction and Classification of Submersibles and Underwater Systems* or an acceptable standard.

1.1.5 When accommodation units are to operate for prolonged periods adjacent to live offshore hydrocarbon exploration or production installations, it is the responsibility of the Owner/Operator to comply with the relevant regulations of the National Administrations in the country of registration and/or the area of operation, as applicable. Special consideration will be given to the safety requirements for classification purposes, *see* Pt 1, Ch 2,1.1.

1.2 Class notations

1.2.1 The Regulations for classification and the assignment of class notations are given in Pt 1, Ch 2, to which reference should be made.

1.2.2 Class notations for fire-fighting units are to be in accordance with Chapter 5.

1.2.3 In general, units complying with the requirements of this Chapter and the relevant Parts of the Rules will be eligible for the assignment of one of the following class type notations, as appropriate:
- Accommodation unit.
- Crane unit.
- Diving support unit.
- Support unit.
- Multi-purpose support unit.
- Pipe laying unit.

1.2.4 Units engaged in more than one function may be assigned a combination of class type notations at the discretion of the Committee.

1.2.5 Support units engaged in more than two functions may be assigned the type notation multi-purpose support unit.

1.2.6 Lifting appliances are to comply with LR's *Code for Lifting Appliances in a Marine Environment*, *see also* Chapter 11.

1.2.7 When the type notation Crane unit is assigned to a unit, the main deck lifting appliances on the unit are considered to form an essential feature and therefore are to be included in the class.

1.2.8 Where the lifting appliances form an essential feature of a classed unit, the special feature class notation **LA** will be assigned, *see* Chapter 11.

1.2.9 Other special features class notations associated with lifting appliances may be assigned, *see* Chapter 11.

1.3 Scope

1.3.1 The following additional topics applicable to the class type notation are covered by this Chapter:
- Strength of structure for accommodation.
- Supports for accommodation modules.
- Structure in way of diving installations.
- Structure in way of cranes.
- Structure in way of pipe laying equipment.
- Bilge systems and cross-flooding arrangements on accommodation units.
- Electrical installations on accommodation units.

1.4 Installation layout and safety

1.4.1 Living quarters, lifeboats and other evacuation equipment are to be located in non-hazardous areas.

1.4.2 The requirements for fire safety are to be in accordance with the requirements of a National Administration, *see* Pt 1, Ch 2,1 and Pt 7, Ch 3.

1.4.3 Additional requirements for safety and communication systems are given in Part 7.

1.5 Plans and data submission

1.5.1 Plans, calculations and data are to be submitted as required by the relevant Parts of the Rules together with the additional plans and information listed in this Chapter.

■ *Section 2* Structure

2.1 Plans and data submission

2.1.1 In addition to the structural plans and information as required by Ch 1,2 and Pt 4, Ch 1,4, the following additional plans and information are to be submitted as applicable:

- Structural plans of the accommodation including deck-houses and modules.
- Design calculations for containerised modules.
- Module support frames or skids and details of attachments.
- Structural arrangements and supports under diving installations.
- Structural arrangements in way of crane supports.
- Structural arrangements and supports under pipe laying equipment.

2.2 General

2.2.1 The general hull strength is to comply with the requirements of Part 4, taking into account the applied weights and forces due to the accommodation, diving installations, pipe laying equipment and cranes, and the local structure is to be suitably reinforced. Attention should be paid to loads resulting from hull flexural effects at support points.

2.2.2 The scantlings of structural deckhouses are to comply with Pt 4, Ch 6,9.

2.2.3 The strength of containerised modules which do not form part of the main hull structure will be specially considered in association with the design loadings.

2.2.4 When containerised modules can be subjected to wave loading or protect openings leading into buoyant spaces, the scantlings are not to be less than required by 2.2.2.

2.2.5 The structural strength of the connections between containerised modules and the supporting frame or structure are to comply with the general strength requirements of Pt 4, Ch 6,9, taking into account the unit's motions and marine environmental aspects.

2.2.6 The connections of containerised modules are also to satisfy an emergency static condition with an applied horizontal force F_H in any direction as follows:

F_H = $W \sin \theta$ N (tonne-f)

where

θ = 25° for semi-submersible units

θ = 17° for self-elevating units

W = weight of the modules supported in N (tonne-f).

2.2.7 In the emergency static condition defined in 2.2.6 the permissible stress levels are to be in accordance with Pt 4, Ch 5,2.1.1(c).

2.3 Watertight and weathertight integrity

2.3.1 The general requirements for watertight and weathertight integrity are to be in accordance with Pt 4, Ch 7.

■ *Section 3* Bilge systems and cross-flooding arrangements for accommodation units

3.1 Application

3.1.1 The requirements of this Section are only applicable to units with accommodation for more than 12 persons who are not crew members. For self-elevating units, *see also* 1.1.1.

3.2 Location of bilge main and pumps

3.2.1 The general requirements of Pt 5, Ch 12 and Ch 13 are to be complied with as applicable unless otherwise specified in this Section.

3.2.2 The bilge main is to be arranged so that no part is situated nearer to the side of the unit than the damage penetration zone.

3.2.3 Where any bilge pump or its pipe connection to the bilge main is situated outboard of the damage penetration zone, a non-return valve is to be fitted at the pipe connection junction with the bilge main.

3.2.4 The emergency bilge pump and its connections to the bilge main are to be situated inboard of the damage penetration zone.

3.2.5 At least three power bilge pumps are to be provided. Where practicable, these pumps are to be placed in separate watertight compartments which will not be readily flooded by the same damage. In units where engines and auxiliary machinery are located in two or more watertight compartments, the bilge pumps are to be distributed throughout these compartments.

3.2.6 The bilge pumping units are to be such that at least one power pump will be available in all circumstances in which the unit may be flooded after damage. This requirement will be satisfied if:

(a) one of the pumps is an emergency pump of the submersible type having a source of power situated above the bulkhead deck or maximum anticipated damage load line; or

(b) the pumps and their power sources are located throughout the length of the unit so that, under any conditions of flooding that the unit is required to withstand by Statutory Regulation, at least one pump in an unaffected compartment will be available.

3.3 Arrangement and control of bilge system valves

3.3.1 The valves and distribution boxes associated with the bilge pumping system are to be arranged to enable any one of the bilge pumps to pump out any compartment in the event of flooding. All the necessary valves for controlling the bilge suctions are to be capable of being operated from above the bulkhead deck or maximum anticipated damage load line. The controls for these valves are to be clearly marked and a means provided at their place of operation to indicate clearly whether they are open or closed.

3.3.2 Where, in addition to the main bilge pumping system, an emergency bilge pumping system is provided, it is to be independent of the main system and so arranged that a pump is capable of pumping out any compartment under flooding conditions. In this case, only the valves necessary for the operation of this emergency system need to be operable from above the bulkhead deck or maximum anticipated damage load line.

3.4 Prevention of communication between compartments in the event of damage

3.4.1 Provision is to be made to prevent any compartment served by a bilge suction pipe being flooded in the event of the pipe being damaged by collision or grounding in any other compartment. For this purpose, where any part of the pipe is situated outboard of the damage penetration zone, or in a duct keel, a non-return valve is to be fitted to the pipe in the compartment containing the open end.

3.5 Cross-flooding arrangements

3.5.1 Cross-flooding arrangements are not permitted as a means of attaining the damage stability criteria in accordance with Pt 4, Ch 7.

3.5.2 Cross-flooding arrangements may be used under control to restore a situation after damage. Such arrangements are not to be automatic or self-acting. Controls are to be situated above the worst anticipated damage waterline.

■ *Section 4*
Additional requirements for the electrical installation

4.1 General

4.1.1 In general, electrical installations are to comply with the requirements of Pt 6, Ch 2.

4.1.2 The requirements of this Section are applicable to units with accommodation for more than 50 persons, who are not crew members.

4.2 Emergency source of electrical power

4.2.1 A self-contained emergency source of electrical power is to be provided.

4.2.2 The emergency source of electrical power, associated transforming equipment, if any, transitional source of emergency power, emergency switchboard and emergency lighting switchboard are to be located above the uppermost continuous deck and be readily accessible from the open deck. They are not to be located forward of the collision bulkhead, where fitted on surface type units.

4.2.3 The location of the emergency source of electrical power and associated transforming equipment, if any, the transitional source of emergency power, the emergency switchboard and the emergency lighting switchboard in relation to the main source of electrical power, associated transforming equipment, if any, and the main switchboard is to be such as to ensure that a fire or other casualty in spaces containing the main source of electrical power, associated transforming equipment, if any, and the main switchboard or in any machinery space of Category A (*see* Pt 7, Ch 3) will not interfere with the supply, control and distribution of emergency electrical power. The space containing the emergency source of electrical power, associated transforming equipment, if any, the transitional source of emergency electrical power and the emergency switchboard is not to be contiguous to the boundaries of machinery spaces of Category A, *see* Pt 7, Ch 3, and those spaces containing the main source of electrical power, associated transforming equipment, if any, or the main switchboard. Where this is not practicable, details of the proposed arrangements are to be submitted.

4.2.4 Provided that suitable measures are taken for safeguarding independent emergency operation under all circumstances, the emergency generator may be used exceptionally, and for short periods, to supply non-emergency circuits.

4.2.5 The electrical power available is to be sufficient to supply all those services that are essential for safety in an emergency, due regard being paid to such services as may have to be operated simultaneously. The emergency source of electrical power is to be capable, having regard to starting currents and the transitory nature of certain loads, of supplying simultaneously at least the following services for the periods specified hereinafter, if they depend upon an electrical source for their operation:

(a) For a period of 36 hours, emergency lighting:
 (i) in all service and accommodation alleyways, stairways and exits, personnel lift cars;
 (ii) in alleyways, stairways and exits, giving access to the muster and embarkation stations;
 (iii) in the machinery spaces and main generating stations including their control positions;
 (iv) in all control stations, machinery control rooms, and at each main and emergency switchboard;
 (v) at all stowage positions for fireman's outfits;
 (vi) at the steering gear;
 (vii) at the fire pump, the sprinkler pump and the emergency bilge pump and at the starting position of their motors;
 (viii) at every survival craft, muster and embarkation station;
 (ix) over the sides to illuminate the area of water into which survival craft are to be launched;
 (x) on helicopter decks.

(b) For a period of 36 hours:
 (i) the navigation lights, other lights and sound signals required by the *International Regulations for the prevention of Collisions at Sea*, in force;
 (ii) the radio communications as required by Amendments to SOLAS 1974 chapter IV as applicable;
 (iii) the navigational aids as required by Amendments to SOLAS 1974 Regulation V/19 as applicable;
 (iv) general alarm and communication systems as required in an emergency;
 (v) intermittent operation of the daylight signalling lamp and the unit's whistle;
 (vi) the fire and gas detection systems and their alarms;
 (vii) emergency fire pump; the automatic sprinkler pump, if any; and the emergency bilge pump and all the equipment essential for the operation of electrically powered remote controlled bilge valves;
 (viii) one of the refrigerated liquid carbon dioxide units intended for fire protection, where both are electrically driven;
 (ix) on column-stabilised units; ballast valve control system, ballast valve position indicating system, draft level indicating system, tank level indicating system and the largest single ballast pump;
 (x) abandonment systems dependent on electric power.

(c) For a period of 24 hours:
 (i) permanently installed diving equipment necessary for the safe conduct of diving operations, if dependent upon the unit's electrical power;
 (ii) the capability of closing the blow out preventer and of disconnecting the unit from the wellhead arrangements, if electrically controlled, unless it has an independent supply from an accumulator battery suitably located for use in an emergency and sufficient for the period of 24 hours.

(d) The steering gear for the period of time required by Pt 5, Ch 19,6.

(e) For a period of four days, any signalling lights or sound signals which may be required for marking offshore structures.

(f) For a period of half an hour:
 (i) any watertight doors if electrically operated together with their control, indication and alarm circuits;
 (ii) the emergency arrangements to bring the lift cars to deck level for the escape of persons. The lift cars may be brought to deck level sequentially in an emergency.

4.2.6 The emergency source of electrical power may be either a generator or an accumulator battery, which are to comply with the following:

(a) Where the emergency source of electrical power is a generator, it is to be:
 (i) driven by a suitable prime mover with an independent supply of fuel having a flashpoint (closed-cup test) of not less than 43°C;
 (ii) started automatically upon failure of the electrical supply from the main source of electrical power and is to be automatically connected to the emergency switchboard; those services referred to in 4.2.5 are then to be transferred automatically to the emergency generating set. The automatic starting system and the characteristics of the prime mover are to be such as to permit the emergency generator to carry its full rated load as quickly as is safe and practicable, subject to a maximum of 45 seconds; and
 (iii) provided with a transitional source of emergency electrical power according to 4.2.7.

(b) Where the emergency source of electrical power is an accumulator battery, it is to be capable of:
 (i) carrying the emergency electrical power without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage;
 (ii) automatically connecting to the emergency switchboard in the event of failure of the main source of electrical power; and
 (iii) immediately supplying at least those services specified in 4.2.7.

4.2.7 The transitional source of emergency electrical power required by 4.2.6 is to consist of an accumulator battery suitably located for use in an emergency, which is to operate without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage and be of sufficient capacity and so arranged as to supply automatically in the event of failure of either the main or emergency source of electrical power at least the following services, if they depend upon an electrical source for their operation:

(a) For half an hour:
 (i) the lighting required by 4.2.5(a) and 4.2.5(b)(i);
 (ii) all services required by 4.2.5(b)(iii), (iv) and (v) unless such services have an independent supply for the period specified from an accumulator battery suitably located for use in an emergency.

(b) Power to operate the watertight doors at least three times, (i.e. closed-open-closed), against an adverse list of 15°, but not necessarily all of them simultaneously, together with their control, indication and alarm circuits as required by 4.2.5(f)(i).

4.2.8 The emergency switchboard is to be installed as near as is practicable to the emergency source of electrical power.

4.2.9 Where the emergency source of electrical power is a generator, the emergency switchboard is to be located in the same space unless the operation of the emergency switchboard would thereby be impaired.

4.2.10 No accumulator battery except for engine starting, fitted in accordance with this Section, is to be installed in the same space as the emergency switchboard. An indicator is to be mounted in a suitable place on the main switchboard or in the machinery control room to indicate when the batteries constituting either the emergency source of electrical power or the transitional source of emergency electrical power are being discharged.

4.2.11 The emergency switchboard is to be supplied during normal operation from the main switchboard by an interconnector feeder which is to be adequately protected at the main switchboard against overload and short-circuit and which is to be disconnected automatically at the emergency switchboard upon failure of the main source of electrical power. Where the system is arranged for feedback operation, the interconnector feeder is also to be protected at the emergency switchboard at least against short-circuit.

4.2.12 In order to ensure ready availability of the emergency source of electrical power, arrangements are to be made where necessary to disconnect automatically non-emergency circuits from the emergency switchboard to ensure that power will be available to the emergency circuits.

4.2.13 Provision is to be made for the periodic testing of the complete emergency system and is to include the testing of automatic starting arrangements.

Section 1 General

1.1 Application

1.1.1 The requirements of this Chapter apply to units intended for fire-fighting operations and are additional to those applicable in other Parts of the Rules.

1.1.2 A unit provided with fire protection and fire-fighting equipment in accordance with these Rules will be eligible for an appropriate class notation.

1.1.3 Requirements additional to these Rules may be imposed by the National Authority with whom the unit is registered and/or by the Administration within whose territorial jurisdiction the fire-fighting unit is intended to operate.

1.2 Class notations

1.2.1 The Regulations for classification and the assignment of class notations are given in Pt 1, Ch 2, to which reference should be made.

1.2.2 Units complying with the requirements of this Chapter and the relevant Parts of the Rules will be eligible for the assignment of one of the following class notations as applicable:

Fire-fighting unit 1 (total monitor discharge capacity in brackets).
Fire-fighting unit 2 (total monitor discharge capacity in brackets).
Fire-fighting unit 3 (total monitor discharge capacity in brackets).
Fire-fighting unit 1 (total monitor discharge capacity in brackets) with water spray.
Fire-fighting unit 2 (total monitor discharge capacity in brackets) with water spray.
Fire-fighting unit 3 (total monitor discharge capacity in brackets) with water spray.

1.2.3 The notation **Fire-fighting unit 1** or **Fire-fighting unit 2** or **Fire-fighting unit 3** signifies that a unit complies with these Rules and is provided with the appropriate fire-fighting equipment described in Table 5.1.1, with the total discharge capacity of monitors in m^3/h shown in brackets.

Table 5.1.1 Fire-fighting equipment

Equipment	Fire-fighting unit 1	Fire-fighting unit 2	Fire-fighting unit 3
Minimum total pump capacity, m^3/h	2400	7200	10 000
Minimum number of water monitors	2	3	4
Minimum discharge rate per monitor, m^3/h	1200	1800	1800
Minimum height of trajectory of jets of monitors above sea level, metres	45	70	70
Minimum range of monitor jets, metres	120	150	150
Minimum fuel capacity for monitors, hours	24	96	96
Number of hose connections each side of unit	4	8	8
Number of fireman's outfits	4	8	8

1.2.4 The addition of the words **with water spray** to the notations referred to in 1.2.3 signifies that a unit is provided with a water spray system which will provide an effective cooling spray of water over the vertical surfaces of the unit to enable it to approach a burning installation for fire-fighting purposes. The requirements for such a system are set out in Section 4.

1.2.5 Support units may be assigned additional class type notations when appropriate, *see* Ch 4,1.2.

1.3 Surveys

1.3.1 The requirements for surveys are given in Pt 7, Ch 3,1.3 of the Rules for Ships, which are to be complied with where applicable.

1.4 Plans and data submission

1.4.1 The requirements for submission of plans are given in Pt 7, Ch 3,1.4 of the Rules for Ships, which are to be complied with where applicable.

1.5 Definitions

1.5.1 The requirements for definitions are given in Pt 7, Ch 3,1.5 of the Rules for Ships, which are to be complied with where applicable.

Section 2
Construction

2.1 General

2.1.1 The requirements for construction are given in Pt 7, Ch 3,2 of the Rules for Ships, which are to be complied with where applicable.

Section 3
Fire-extinguishing

3.1 General

3.1.1 The requirements for fire-extinguishing are given in Pt 7, Ch 3,3 of the Rules for Ships, which are to be complied with where applicable.

Section 4
Fire protection

4.1 General

4.1.1 The requirements for fire protection are given in Pt 7, Ch 3,4 of the Rules for Ships, which are to be complied with where applicable.

Section 5
Lighting

5.1 General

5.1.1 The requirements for lighting are given in Pt 7, Ch 3,5 of the Rules for Ships, which are to be complied with where applicable.

■ *Section 1*
Strengthening standard for navigation in first-year ice conditions – Application of requirements

1.1 General

1.1.1 Where additional strengthening is fitted in accordance with the requirements given in Section 2, an appropriate special features notation will be assigned. It is the responsibility of the Owner to determine which notation is most suitable for his requirements.

1.1.2 The requirements for strengthening for navigation in ice as given in Section 2 are intended for units operating in first-year ice irrespective of whether assistance from ice breakers is anticipated. They are not intended for units designed to operate in multi-year ice conditions.

1.1.3 For semi-submersible units with twin lower hulls the ice strengthening, as required by this Chapter, is to be carried out to both hulls. Where the exposed deck of the lower hulls is situated below the upper limit of the ice belt, the strengthening of the deck will be subject to special consideration and the deck thickness is not to be less than the shell plating in the main ice belt.

1.1.4 General requirements for units intended for operation in ice are given in Pt 8, Ch 1 of the Rules for Ships.

1.1.5 The machinery requirements for navigating in first year ice conditions are given in Pt 8, Ch 2,7 and 9 of the Rules for Ships.

■ *Section 2*
Strengthening requirements for navigation in first-year ice conditions

2.1 General

2.1.1 The strengthening requirements for navigation in first-year ice conditions are given in Pt 8, Ch 2,6 and 8 of the Rules for Ships, which are to be complied with where applicable.

■ *Section 3*
Operation in ice at a fixed location

3.1 General requirements

3.1.1 When a unit is required to operate at a fixed location in ice conditions the designer/Builder is required to submit a rational analysis for determining the maximum operating ice pressures on the structure based on acceptable environmental data.

3.1.2 The minimum design temperature of the structure and steel grades will be specially considered, *see also* Pt 4, Ch 2.

3.1.3 The extent of additional strengthening will be specially considered by LR and an additional structural analysis of the primary structure may be required.

3.1.4 When a unit operates in areas where there is the possibility of collision with icebergs, appropriate data is to be submitted and the structure suitably strengthened for the collision loads.

3.1.5 When units are fitted with riser systems the arrangements are to be designed to minimise the effect of ice loadings on the risers.

3.1.6 Suitable steam generating equipment, or an equivalent means, are to be provided with outlets and hoses, to keep designated areas free of ice and snow such that operation/maintenance operations may be conducted safely. Such equipment is to be capable of being used in at least the following locations:
- The working areas.
- The helicopter deck.
- Walkways and escape routes.
- Lifeboat embarkation station.

3.1.7 Special requirements will apply to sea inlet chests for machinery cooling and fire pump suctions and reference should be made to the relevant text of Pt 8, Ch 2 of the Rules for Ships. The design and arrangement of sea inlet chests will be specially considered, as applicable to the type of unit.

3.1.8 In the case of self-elevating units where the design of the elevating machinery is required to operate in ice conditions, suitable de-icing equipment is to be provided.

3.1.9 The starting requirements of the emergency generators for low temperature operation is to be in accordance with Pt 5, Ch 2,9.4 of the Rules for Ships.

3.1.10 Electrical equipment and cables likely to be exposed to sustained low temperatures are to be suitably constructed for the ambient conditions in accordance with a recognised National or International Standard.

3.1.11 When a unit has been reinforced and approved by LR for operating in ice a suitable descriptive note will be included in the ClassDirect Live website.

3.2 Plans and data submission

3.2.1 Plans, calculations and data are to be submitted as required by the relevant Parts of the Rules together with the additional information required by this Section.

Section

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter apply to the drilling plant, derricks and flare structures, etc., and drilling-related systems and equipment installed on board drilling units. The requirements of this Chapter are considered to be supplementary to the requirements in the relevant Parts of the Rules.

1.1.2 The Rules cover the approval of the drilling plant which includes the equipment and systems required for safe drilling operations but limited to those aspects defined in 1.3. The approval of the equipment includes all mechanical and structural components of the drilling plant covered by the Rules. The Rules also cover the protection of the environment with regard to pollution.

1.1.3 The operational aspects and reliability of the drilling plant are not covered by class except when they have an effect on the overall safety of the drilling unit, the personnel on board or the environment.

1.1.4 The Rules are framed on the understanding that units with an installed drilling plant facility will not be operated in environmental conditions more severe than those for the design basis and class approval. The drilling facilities are to be considered designed to operate under ambient conditions prevalent in the intended area of operation, and based on relevant MetOcean and climatic data.

1.1.5 It is the responsibility of the Owners/Operators to ensure that the drilling plant facility is properly maintained and operated by qualified personnel and that the test and operational procedures are clearly defined and complied with.

1.1.6 The limiting design criteria on which approval is based are to be stated in the unit's Operations Manual.

1.2 Class notations

1.2.1 The Regulations for classification and the assignment of class notations are given in Pt 1, Ch 2, to which reference is to be made.

1.2.2 Units fitted with an installed drilling plant facility which complies with the requirements of this Chapter, or recognised Codes and Standards agreed with LR, will be eligible for the assignment of the special features class notation **DRILL**.

1.2.3 When a unit is to be verified in accordance with the Regulations of a Coastal State Authority, an additional descriptive note may be assigned in accordance with Pt 1, Ch 2.

1.2.4 The latest issue of the following referenced standards is to be used unless otherwise agreed beforehand. Other recognised Standards may be used provided it can be shown that they meet or exceed the requirements of the referenced standards in Appendix A. When other codes or standards are proposed, gap analysis and risk assessments are to be provided by the dutyholder to demonstrate an equivalent level of safety to the recognised Standards in this notation.

1.3 Scope

1.3.1 Goal:

(a) The drilling plant is to be designed, constructed, installed and maintained satisfactorily for the intended service conditions in order to minimise the risk to the unit, personnel on board and to the environment. The drilling plant is to be operated and maintained by competent personnel.

(b) All drilling plants, regardless of design, are to comply with this goal. The prescriptive requirements in this Section are considered to provide a route to meeting this goal. Alternative arrangements which are considered by LR also to meet this goal will be accepted.

(c) Apart from other hazards noted elsewhere in these Rules, examples of some hazards specifically related to drilling operations are as follows:
- Blow out.
- Hydrogen sulphide and other toxic gases.
- Uncontrolled release of hydrocarbon gases.
- Loss of position.
- Fire or explosion.
- Loss of positive pressurisation in hazardous spaces or equipment.
- Ventilation in hazardous areas.
- Dropped objects.
- Failure of Zone management systems.
- Punch through (bottom supported units).
- Shallow gas (stability and fire risks).
- Radioactivity.
- Environmental spills.

Risk assessments are to be made by the dutyholder with regard to mitigating or limiting the effects of these and any other similar related hazards.

1.3.2 Any part, component or structure of the drilling system that is required to allow the rig to conduct drilling or well testing operations. This includes any outlet from hydrocarbon flares and vent systems, and includes the sub-sea blow out preventer stack, risers, conductors and any other subsea component that is required to allow drilling operations from the unit to be conducted but does not include subsea production equipment.

1.4 Plant design characteristics

1.4.1 The design and arrangement of the drilling plant, derricks and flare structures, etc., are to comply with the requirements of this Chapter and/or recognised Codes and Standards, *see* 1.5.

1.4.2 Attention is to be given to the relevant Statutory Regulations of the National Administrations in the country of registration and the area of operation, as applicable.

1.4.3 The plant and supporting structures above the deck are to be designed for all operating and transit conditions in accordance with recognised and agreed Codes and Standards, suitably modified to take into account the unit's motions and marine environmental aspects. Except for the emergency condition, as detailed in 1.4.4, the total stress in any component of the plant is not to exceed the Code value at the temperature concerned, unless expressly agreed otherwise by LR, whether the plant is operative or non-operative, when subjected to any of the following loads, as applicable:

- Static and dynamic loads due to wave-induced motions of the unit.
- Loads resulting from hull flexural effects at the plant support points, as appropriate.
- Direct wind loads.
- Normal gravity and functional loads.
- Thermal loads, as appropriate.
- Ice and snow loads, as appropriate.

1.4.4 In general, the plant and supporting structures above the deck are to be designed for an emergency static condition with the unit inclined to the following angle:

- Column-stabilised units:
  25° in any direction.
- Surface type units:
  22,5° heel, port and starboard, and trimmed to an angle of 10° beyond the maximum normal operating trim.
- Self-elevating units:
  17° in any direction in transit conditions only.

These angles may be modified by LR in particular cases as considered necessary. In no case is the inclined angle for the emergency static condition to be taken less than the maximum calculated angle in the worst damage condition in accordance with the appropriate damage stability criteria.

1.4.5 In the emergency condition defined in 1.4.4, the plant is to be assumed to have maximum operating weights, temperatures and pressures, unless agreed otherwise with LR. When applicable, the plant is also to be subjected to ice and snow loads. Wind loads need not be considered to be acting during this emergency condition. The total stress in any component of the plant or support structure above the deck is not to exceed the minimum yield stress of the material.

1.4.6 The permissible stresses in the primary hull structure below plant and equipment supports in transit, operating and emergency conditions are to be in accordance with Pt 4, Ch 5.

1.4.7 The design of the plant is to allow for adequate space and services for completion and intervention equipment, such as, but not limited to, wire line, logging, coiled tubing, snubbing, well completion, work over and well testing. The location is also to take into consideration the requirement for hazardous area classification of equipment and services. Communication and safety systems are also required to be considered in the design.

1.5 Recognised Codes and Standards

1.5.1 Installed drilling plant facilities designed and constructed to standards other than the Rule requirements will be considered for classification, subject to the alternative standards being agreed by LR to give an equivalent level of safety to the Rule requirements. It is essential that in such cases LR is informed of the Owner’s proposals at an early stage, in order that a basis for acceptance of the standards may be agreed. Refer to Appendix A for applicable international Codes and Standards considered by LR as an equivalent level of safety to Rule requirements.

1.5.2 In general, the requirements in this Chapter are based on internationally recognised Codes and Standards for the drilling plant structures and drilling related systems and equipment as defined in Appendix A. Other Codes and national Standards may be used after special consideration and prior agreement with LR. When considered necessary, additional Rule requirements are also stated in this Chapter.

1.5.3 Where necessary, the Codes and Standards are to be suitably modified and/or adapted to take into account all marine environmental aspects.

1.5.4 The agreed Codes and Standards may be used for design, construction and installation but where considered applicable by LR, compliance with the additional requirements stated in the Rules is required. Where there is any conflict, the Rules will take precedence over the Codes or Standards.

1.5.5 The mixing of Codes or Standards for each equipment item or system is to be avoided. Deviation from the Code or Standard must be specially noted in the documentation and approved by LR.

1.6 Equipment categories

1.6.1 The approval and certification of drilling equipment is to be based on equipment categories agreed with LR.

1.6.2 Drilling equipment, including its associated pipes and valves, is to be divided into equipment categories **1A**, **1B** and **II**, depending on the complexity of manufacture and its importance with regard to the safety of personnel and the installation and the possible effect on the environment.

1.6.3 The following equipment categories are used in the Rules:

1A Equipment of primary importance to safety for which design verification and survey during fabrication are considered essential. Equipment in this category is of complicated design/manufacture and is not normally mass produced.

1B Equipment of primary importance to safety for which design verification and witnessing the product quality are considered essential. Equipment in this category is normally mass produced and not included in category **1A**.

II Equipment related to safety which is normally manufactured to recognised Codes and Standards and has proven reliability in service, but excludes equipment in category **1A** and **1B**.

1.6.4 A guide to equipment and categories is given in Appendix A. A full list of equipment categories for each drilling plant facility is to be agreed with LR before manufacture. Minor equipment components need not be categorised.

1.7 Equipment certification

1.7.1 Drilling equipment is to be certified in accordance with the following requirements:

(a) Category **1A**
- Design verification and issue of certificate of design strength approval.
- Pre-inspection meeting at the suppliers with agreement and marking of quality plan and inspection schedule.
- Survey during fabrication and review of fabrication documentation.
- Final inspection with monitoring of function/pressure/load tests and issue of a certificate of conformity.

(b) Category **1B**
- Design verification and issue of certificate of design strength approval, where applicable, and review of fabrication documentation.
- Final inspection with monitoring of function/pressure/load tests and issue of certificate of conformity.

(c) Category **II**
- Supplier's/manufacturer's works' certificate giving equipment data, limitations with regard to the use of the equipment and the supplier's/manufacturer's declaration that the equipment is designed and fabricated in accordance with recognised Standards or Codes.

1.7.2 All equipment recognised as being of importance for the safety of personnel and the drilling plant installation is to be documented by a data book.

1.8 Fabrication records

1.8.1 Fabrication records are to be made available for Categories **1A** and **1B** equipment for inspection and acceptance by LR Surveyors. These records are to include the following:
- Manufacturer's statement of compliance.
- Reference to design specification and plans.
- Traceability of materials.
- Welding procedure tests and welders' qualifications.
- Heat treatment records.
- Records/details of non-destructive examination.
- Load, pressure and functional test reports.

1.9 Installation of drilling plant equipment

1.9.1 The installation of drilling equipment on board the unit is to be controlled by LR in accordance with the following principles:
- All Category **1A** and **1B** equipment delivered to the unit is to be accompanied by a certificate of design strength approval and an equipment certificate of conformity and all other necessary documentation.
- All Category II equipment delivered to the unit is to be accompanied by equipment data and a works' certificate.
- Control and follow-up of non-conformities/deviations specified in design certificates and certificate of conformity.
- Ongoing survey and final inspection of the installed production and process plant.
- Monitoring of functional tests after installation on board in accordance with an approved test programme.
- Issue of a plant installation report.

1.9.2 A test procedure, including acceptance criteria and functional description prior to the factory acceptance test of equipment, system or sub-system, is to be provided.

Mechanical completion to the satisfaction of LR is to be completed prior to starting or testing of any drilling equipment or system. The commissioning procedures are to contain all necessary information required to ensure safe start-up and shut-down of each equipment or system. All equipment and system operating and maintenance manuals are to be made available to LR before final commissioning.

The drilling package will undergo a final drilling trial before delivery, in accordance with Section 11. All drilling equipment and related systems will be required to operate simultaneously with simulated drilling loads and operate as close to the normal drilling operations design as possible. All drilling instrumentation and sensors will also be included in the trial. A guidance note on how to conduct final trials will be made available for the Owner.

1.10 Maintenance and repair

1.10.1 It is the responsibility of the Owners/Operators to ensure that installed drilling plant is maintained in a safe and efficient working condition in accordance with the manufacturer's specifications.

1.10.2 When it is necessary to repair or replace installed drilling plant, any repaired or spare part is to be subject to the equivalent certification as the original part.

1.10.3 The design and layout of the drilling systems are to provide safe working arrangements for operation and maintenance. Use of man-riding winches or baskets for routine maintenance should be discouraged.

1.10.4 Sufficient tools and test equipment to ensure safe and continued operation of the drilling plant are to be provided. Suitable tools and equipment for working at height and for use in hazardous areas are also be provided.

1.11 Plans and data submissions

1.11.1 Plans, calculations and data are to be submitted as required by the relevant Parts of the Rules, together with the additional plans and information listed in this Chapter. Plans are to be submitted in triplicate, but only a single copy of supporting documents and calculations is required.

■ *Section 2* **Structure**

2.1 Plans and data submissions

2.1.1 The following additional plans and information are to be submitted:

- General arrangement plans of the drilling plant.
- Drilling derrick structural plans and design calculations.
- Raw water towers' structural plans and design calculations.
- Flares structures' structural plans and design calculations.
- Structural plans of equipment skids, support stools and design calculations.
- Structural plans of supports to lifting appliances.

2.2 Materials

2.2.1 Materials are to comply with Ch 1,4 and material grades are to comply with Pt 4, Ch 2 using the categories defined in this Section.

2.2.2 Support structures for the drilling plant are to be divided into the following categories:

- Primary structure.
- Secondary structure.

2.2.3 Main load-bearing members and elements subjected to high tensile or shear stresses are defined as primary structure. All other structure is considered to be secondary structure.

2.2.4 Some specific examples of structural elements which are considered as primary structure are as follows:

- Derrick legs and base plates.
- Derrick principal cross bearing.
- Derrick crown block/water table supports.
- Derrick bolts.
- Support stools (attached to the main/upper deck).
- Main legs, chords and end connections.
- Foundation bolts.

2.3 Supporting structure interfaces

2.3.1 The design loadings for all structures supporting plant, including equipment skids, support stools, tanks and storage vessels, are to be defined by the designers/Builders and calculations are to be submitted in accordance with an appropriate Code or Standard, *see* Appendix A.

2.3.2 The design of supporting structures for drilling facilities is to integrate with the primary hull under-deck structure.

2.3.3 The permissible stresses in the hull structure below the drilling plant are to be in accordance with Pt 4, Ch 5 and the local strength is to comply with Pt 4, Ch 6.

2.3.4 The BOP frame, lifting points or supports are to meet the requirements of API RP 2A-WSD.

2.4 Derrick and masts

2.4.1 The structural design of drilling derricks is to be in accordance with a recognised Code of Practice, such as API Spec 4F or acceptable equivalent, *see* Appendix A. The design conditions defined in 1.4 are to be complied with.

2.4.2 When the unit is to operate in an area which could result in the build-up of ice on the drilling derrick, the effects of ice loading are to be included in the calculations, *see* Pt 4, Ch 3. The design criterion for this condition may be taken as a non-drilling condition with defined setback loading. The environmental criteria are to be agreed with LR, but in general may be based on five-year return criteria for the operating location.

2.4.3 The structural design of the drilling derrick may be required by LR to include the effect of fatigue loading, *see* Pt 4, Ch 5.

2.4.4 Fatigue damage calculations for individual components when required are to take account of the degree of redundancy and also the consequence of failure.

2.4.5 Where National Administrations give specific requirements with respect to fatigue design, it is the responsibility of the Owners to comply with such Regulations.

(a) The design of the derrick or mast and associated ancillary equipment is to incorporate features to reduce the risk to personnel during routine maintenance or operations.
(b) The design is to allow for suitable and safe access from deck or installed work platforms for operation, maintenance and inspection services. All items in the derrick are to be accessible for routine inspection, without the need for man-riding winches.
(c) Where direct access to lubrication points such as crown or deflector sheaves cannot be provided, the use of remote grease lines can be incorporated.
(d) The design is to also allow for extra hang off points for temporary equipment such as wire line units.
(e) Portable equipment such as catwalk samson posts are also to be fitted with padeyes to allow safe removal and re-location.
(f) All padeyes are to be designed, installed and tested to LR requirements, and all padeyes are to be identified and a record book kept, allowing for inspection records to be maintained.
(g) Consideration is to be given to providing access and means to fight a major fire at the monkey board level. The means to fight a fire at this level are to include portable and fixed fire-fighting systems.
(h) Modification to any part of the derrick or mast from original design will require OEM and LR design approval, followed by trials if necessary.
(j) Temporary installed structures, members or fittings are to undergo an assessment by the dutyholder to confirm they will not affect the original design; if the design is affected, details are to be submitted for approval.
(k) Casing stabbing boards are to comply with the following requirements:
   - The hoisting system is to be designed and constructed to Codes and Standards approved by LR.
   - Permanent safe access to the stabbing board for operators and maintenance personnel is to be provided.
   - Any rack and pinion system is to be designed so that the working platform will not fall if the rack or pinion should fail, and a single or common mode failure cannot occur.
   - Where winch systems are used, the rope is to spool evenly on the drum and there are to be at least three full turns of rope remaining on the drum at all times.
   - The rope is to remain captive with the drum and sheave systems under all service conditions, including slack rope conditions.
   - Upper and lower-level limit switches are to ensure that the hoist system does not operate beyond its specified range.
   - Casing stabbing boards is to be clearly marked 'SUITABLE FOR CARRYING PEOPLE' and with the number of people they can carry.
   - Casing stabbing boards and other working platforms that are raised and lowered by a powered or manually operated system are to provide users with a secure and safe means of travel and support at the point of work.
   - The working platform is to be positively guided by rails or runners. The guidance system is to ensure that the platform remains captive to its rails or runners under all circumstances, including any wheel or roller failure or failure of the primary hoisting system.
   - Rails/runners are to be securely attached to their supports and are to not open up under static operations, travelling or other dynamic operations, overload testing or operation of the secondary control/braking system.
   - The working platform is to have non-slip standing surfaces, handrails, mid-rails and edge protection.
   - The platform is to also have anchorage points for inertia-type safety harnesses.
   - Control of the primary lifting system is to provide smooth movement of the working platform. The control lever is to spring to neutral on release, effectively braking the primary hoisting system.
   - Where a manual system of raising or lowering the platform is used, a positive locking system such as a ratchet-and-pawl mechanism is to be provided in addition to the service brake.
   - A secondary, inertia-type brake, acting at the rails, is to be provided in case there is any failure in the primary hoisting system. The secondary brake is to act independently of the primary brake and not require any power source (hydraulic, electrical or pneumatic) for its operation.
   - Each braking system is to be capable of holding the full rated capacity of the loaded stabbing board plus allowances for dynamic effects. It is not to be possible to lower the working platform by brake operation only. Two locking devices are to be provided, such that one locking device operates when the lifting handle is at neutral and the other one operates if the hoist mechanism fails. Each device is to be independent.
   - A speed controlling device is to prevent the raising and lowering speed of the platform exceeding tripping speed.
   - Adequate safety gear of the progressive type is to be provided, designed to engage within freefall conditions.
   - The platform is to be equipped with a latch lock mechanism which secures it when not in motion.

2.5 Water towers

2.5.1 Water towers on self-elevating units are to be designed in accordance with a recognised Code or Standard, modified to take into account the unit's motions and marine environmental aspects, *see* Appendix A. Provisions for effective securing of towers when the unit is in transit is also to be similarly designed. The design conditions defined in 1.4 are to be complied with.

2.5.2 The structural design of the tower is to include the effect of fatigue loading, *see* Pt 4, Ch 5.

2.5.3 Where National Administrations give specific requirements with respect to fatigue design, it is the responsibility of the Owners to comply with such Regulations.

2.5.4 For slender structures and components, the effects of wind induced cross-flow vortex vibrations are to be assessed.

2.5.5 Wind loads are to be calculated in accordance with LR's *Code for Lifting Appliances in a Marine Environment* (hereinafter referred to as LAME Code), or a recognised Code or Standard, *see* Appendix A.

2.5.6 The permissible stresses in the hull structure below the tower are to be in accordance with Pt 4, Ch 5.

2.6 Flares structures

2.6.1 Flares structures are to be designed in accordance with the requirements of a recognised Code or Standard, *see* Appendix A. The design conditions defined in 1.4 are to be complied with.

2.6.2 The flare structures are also to be designed for the imposed loads due to handling the structure and when in the stowed position.

2.6.3 The designers/Builders are to specify the maximum weight of the burner and spreader and the design criteria defined in 1.4.

2.6.4 The structural design of flare structures is to include the effect of fatigue loading and the thermal loads during flaring, *see* Pt 4, Ch 5.

2.6.5 Where National Administrations give specific requirements with respect to fatigue design, it is the responsibility of the Owners to comply with such Regulations.

2.6.6 For slender structures and components, the effects of wind induced cross-flow vortex vibrations are to be assessed.

2.6.7 Wind loads are to be calculated in accordance with LR's LAME Code or a recognised Code or Standard, *see* Appendix A.

2.6.8 Permissible stresses in the hull structure below the flare structure supports are to be in accordance with Pt 4, Ch 5.

2.7 Lifting appliances

2.7.1 Lifting appliances shall, as a minimum, meet the requirements of the following Standards and are to comply with LR's LAME Code, and where applicable, PUWER Reg 4 and LOLER Reg 5. *See also* Chapter 11.

API Spec 2C	*Specification for offshore pedestal mounted cranes*.
API RP 2D	*Operation and maintenance of offshore cranes*.
ASME B30.20	*Below-the-hook lifting devices*.

BOP handling systems will meet the minimum requirements of API Spec 7K.

Hoisting appliances are to be located such as to ensure safe operation, and must be suitably protected if for location in a hazardous area. Protection is to limit surface temperature to a maximum of 80 per cent of auto-ignition temperature. This temperature, if unknown, may be taken to be a maximum of 200°C.

Submitted design data for hoisting appliances is to include all load and hoisting/lowering speed combinations at the rope drum.

Man-riding winches are to be of an approved type and certified for offshore use, and they are to comply with the following requirements:

(a) Two fail safe brakes are to be provided, one automatic and the other manual.
(b) Hydraulic winches may be provided with a regenerative brake system with breaking valve, in place of a secondary manual brake.
(c) The operating lever is to be returned to neutral upon release in any position.
(d) Declutching devices are not to be fitted, unless otherwise agreed by LR, *see* (e).
(e) 'Sprag' type unidirectional bearings (freewheels) are acceptable subject to regular satisfactory in-service inspection.
(f) Lowering under normal operating conditions is to be through control of the motor.
(g) Means for prevention of overriding and underriding of the winch is to be provided, where reasonably practicable.
(h) Manufacturer's label indicating operational parameters and approval for man-riding.
(j) A sign affixed to the winch, clearly indicating suitability for man-riding (for example, 'SUITABLE FOR MAN-RIDING').
(k) The winch operating lever must automatically return to neutral when released.
(l) An automatic brake that will engage upon returning the operating lever to neutral.
(m) A manual brake.
(n) A guide for spooling the wire rope onto the drum (manual or automatic).
(o) The ability to lower the rider in a controlled manner in the event of loss of power to the winch.
(p) An emergency disconnect from the power source (ESD) located within winch operator's reach.

2.8 Guard rails and ladders

2.8.1 It is the Owners' responsibility to provide permanent access arrangements and protection by means of Ladders and guard rails. It is recommended that such arrangements are designed in accordance with a recognised Code or Standard.

2.8.2 Dutyholders should be aware that the hoops of a ladder alone may not be effective in safely arresting a fall without injury. Dutyholders are therefore advised to review their risk assessments and consider if additional fall protection is required or alternative means of access is to be supplied.

Where dutyholders choose to use fall arrest equipment inside a hooped ladder to arrest a fall, they should be aware that hoops may interfere with the operation of some types of fall arrest equipment (for example, inertia reel devices). Dutyholders should contact their manufacturer or supplier for advice on the performance of such equipment when used in a hooped ladder.

Users of fall arrest equipment inside a caged ladder should also be aware of the possibility of injury from striking the cage following a fall. The use of climbing helmets to reduce the risk of injury may need to be considered (refer to HSE CCID 1-2012).

Where ladders are used as (or part of) an emergency escape route, they are to be fire resistant to comply with BS 476 part 7, 1989 or equivalent.

Ladders fixed and portable are to be suitable for use in the intended areas, and the Owner is to conduct risk assessments with regard to the use of wooden or aluminium ladders in an offshore drilling environment.

Ladders used as an escape to sea are also to be included in the unit's inspection and maintenance planning.

2.9 Fire and blast loading

2.9.1 Particular consideration is to be given to the potential effects of fire and blast impinging on exposed boundary bulkheads of accommodation spaces and/or temporary refuge. Where boundary bulkheads can be subjected to blast loading, the scantlings are to comply with Pt 4, Ch 3,4.16 and Ch 6,9.1.6.

Other Standards which will apply to fire and blast loading include:

API RP 2FB *Recommended practice for design of offshore facilities against fire and blast loading*.

■ *Section 3* Drilling plant systems

3.1 Plans and particulars

3.1.1 Plans and particulars showing arrangement of the drilling plant equipment, systems, functional descriptions and operating philosophies are to be submitted for approval. Where considered necessary, risk assessments are also to be submitted for consideration.

3.1.2 The submitted information is to include the following as applicable to the equipment categories:

- Design specification, including data of working medium and pressures.
- Minimum/maximum temperatures, corrosion allowance, environmental and external loads.
- Plans, including sufficient detail and dimensions to evaluate the design.
- Strength calculations as applicable.
- Material specifications and welding details.

Drilling equipment is to be designed in accordance with internationally recognised and agreed Codes and Standards and in accordance with the requirements of Section 1.

3.1.3 The generally recognised Codes and Standards frequently specified for drilling equipment are included in these Rules. These Codes and Standards may be used for certification but the additional requirements given in these Rules apply and will take precedence over the Codes and Standards wherever conflict occurs.

3.1.4 The selected materials are to be suitable for the purpose intended and must have adequate properties of strength and ductility. Materials used in welded construction are to be of known and documented weldable quality.

3.1.5 For selection of acceptable materials suitable for hydrogen sulphide-contaminated products (sour service), reference is made to NACE MR0175/ISO15156 – *Petroleum and Natural Gas Industries – Materials for use in H2S-containing Environments in Oil and Gas Production*, *see* Appendix A.

3.1.6 Grey iron castings are not to be used for critical components.

3.1.7 Proposals to use spheroidal graphite iron castings for critical components operating below 0°C will be specially considered by LR in each case.

3.1.8 In general, bolts and nuts are to comply with the Standards listed in Appendix A, A1.2.

3.1.9 Bolts and nuts for major structural and mechanical components are to have a tensile strength of not less than 600 N/mm^2. Galvanising of high tensile bolts and nuts is to be avoided. Where non high tensile bolts and nuts are galvanised, they are to follow the guidelines of ASTM B695.

3.1.10 The risk of galvanic corrosion is also to be considered in the selection of all types of fasteners.

3.1.11 For general service, the specified tensile strength of bolting material is not to exceed 1000 N/mm^2.

3.1.12 Where required, materials of high heat resistance are to be used and the ratings are to be verified.

3.1.13 All bolted structures are to have specific installation and tensioning design requirements made available to the Owner and LR for review before assembly.

3.2 General requirements for piping systems

3.2.1 The design and construction of the piping systems, piping and fittings forming part of such systems are to be in accordance with an acceptable Code or Standard, *see* 1.5, and are also to comply with the remainder of this Section.

3.2.2 Piping systems for the drilling and well-testing installations are, in general, to be separate and distinct from piping systems essential to the safety of the unit. Notwithstanding this requirement, this does not exclude the use of the installation's main, auxiliary and/or essential services for drilling plant operations in suitable cases. Attention is drawn to the relevant Chapters of Part 5, Main and Auxiliary Machinery, when such services are to be utilised. Substances which are known to present a hazard due to a reaction when mixed are to be kept entirely separate.

3.2.3 Piping for services essential to the drilling operations, and piping containing hydrocarbon or other hazardous fluids, is to be of steel or other approved metallic construction. Piping material for H_2S-contaminated products (sour service) is to comply with the NACE MR0175/ISO15156 – *Petroleum and Natural Gas Industries – Materials for use in H2S-containing Environments in Oil and Gas Production*, *see* Appendix A.

3.2.4 All piping systems are to be suitable for the service intended and for the maximum pressures and temperatures to which they are likely to be subjected.

3.2.5 In mud, cement or other systems where the piping is likely to be subjected to considerable erosion, a suitable erosion allowance is to be specified, and anticipated service conditions such as vibration, velocity, hydraulic hammer pressure pulsations are also to be taken into account.

3.2.6 The number of detachable pipe connections in the drilling piping systems is to be limited to those which are essential for mounting and dismantling. Non-critical auxiliary systems such as water and air service may be attached with approved detachable couplings.

3.2.7 Valves used for the shutting down and control of equipment in an emergency, such as choke manifolds and standpipe manifolds, are to be provided with indicators to show clearly whether they are open or closed.

3.3 Flexible piping

3.3.1 Flexible piping elements approved for their Intended use may be installed in locations where rigid piping is unsuitable or impracticable. Such flexible elements are to be accessible for inspection and replacement, and are to be secured and protected so that personnel will not be injured in the event of failure.

3.3.2 All flexible hoses used during drilling operations are to be manufactured to a recognised Code or Standard and a prototype hose with end fittings attached is to have been burst-tested to the minimum pressure stipulated by the appropriate Standard. Transfer, mud, hydraulic and pneumatic hoses which may be liable to heavy external wear are to be specially protected. Protection against mechanical damage and from rushing/compression is to be provided where necessary.

3.3.3 Means are to be provided to isolate flexible hoses if used in systems where uncontrolled outflow would be critical.

3.3.4 Kill, choke and jumper hoses are to meet the minimum requirements of API 16C and API RP53.

3.3.5 Hydraulic control hoses serving well completion units and blow out preventers are to meet the requirements of API Spec 16E and API RP53.

3.3.6 Flexible piping is to meet the requirements of API RP 17B/ISO 13628-11:2007 *Recommended Practice for Flexible Pipe*. Inspection and maintenance procedures of flexible lines are to meet with requirements of API RP 7L.

3.3.7 Fiberglass and plastic pipe are to meet the requirements of the following main Standards and where applicable other standards in Appendix A:

API RP 15CLT	*Recommended practice for composite lined steel tubular goods*.
API Spec 15HR	*Specification for high pressure fiberglass line pipe*.
API Spec 15LE	*Specification for polyethylene line pipe (pe)*.
API Spec 15LR	*Specification for low pressure fiberglass line pipe*.

3.4 Design and construction

3.4.1 The design strength of drilling equipment is to comply generally with LR agreed Codes and Standards.

3.4.2 Drilling equipment and systems are to be protected from excessive loads and pressures.

3.4.3 All drilling equipment is to be located in order to ensure safe operation, and must be suitably protected if for location in a hazardous area. Protection is to limit surface temperature to a maximum of 80 per cent of auto-ignition temperature. This temperature, if unknown, may be taken to be a maximum of 200°C.

3.4.4 The equipment is to be suitable for the design environmental conditions for the unit and the submitted design data for drilling equipment is to include all loading conditions, for each item, including the most unfavourable combination of loads, and any external loading conditions.

3.4.5 A dedicated area suitably sized and classified for well test equipment is to be provided. The area is to be suitably protected with bunding and drainage to prevent any oil spillage from spreading to other areas of the unit.

3.4.6 All areas that are intended to contain permanent or temporary equipment are to be designed with utilities such as electrical power, fresh water, compressed air, PA system, ESD, firewater and/or deluge system and communication system.

3.4.7 The drilling plant will be designed and constructed with regard to safe handling and storage of heavy equipment.

3.4.8 Suitable drilling plant control systems are to be provided; as a minimum, these are to display drilling data, audible and visual alarms, anti-collision systems status, necessary process and storage systems data and are to control the mechanical and electrical equipment and other necessary utilities for safe drilling operations.

3.4.9 The drilling plant is to be equipped with sufficient emergency stops in critical areas. Details of the drilling plant emergency alarm system are to be submitted to LR for review.

3.4.10 The drilling plant will be designed to reduce the potential of ignitions arising from static, lightning and stray currents.

3.5 Drilling equipment

3.5.1 All drilling equipment shall, as a minimum, meet the requirements of the following main Standards and where applicable other standards referenced in Appendix A.

Consideration is to be given during the design and installation of all drilling equipment to reducing the risk to personnel during routine maintenance or operations:

API Spec 7-1	*Specification for rotary drill stem elements.*
API Spec 7K	*Specification for drilling and well servicing equipment*.
API RP 7G	*Recommended practice for drill stem design and operating limits*.
API Spec 8A	*Specification for drilling and production hoisting equipment.*
API RP 8B	*Recommended practice for procedures for inspection, maintenance, repair, and remanufacture of hoisting equipment*.
API Spec 9A	*Specification for wire rope*.
API RP 9B	*Recommended practice on application, care and use of wire rope for oil-field service*.
API Spec 7F	*Oil-field chain and sprockets*.
API RP 7L	*Procedures for inspection, maintenance, repair, and remanufacture of drilling equipment*.
API Spec 8A	*Specification for drilling and production hoisting equipment*.
API RP 8B/ ISO 13534:2000	*Recommended practice for procedures for inspection, maintenance, repair, and remanufacture of hoisting equipment*.
API Spec 8C/ ISO 13535:2000	*Specification for drilling and production hoisting equipment (psl 1 and psl 2)*.
API Spec 9A	*Specification for wire rope.*
API RP 9B	*Recommended practice on application, care and use of wire rope for oil-field service*.
API RP 13C/ ISO 13501	*Recommended practice on drilling fluid processing systems evaluation*.
API RP 2003	*Protection against ignitions arising out of static, lightning and stray currents*.
API RP 7HU1	*Safe use of 2-Inch hammer unions for oilfield applications*.

3.6 Drilling well control equipment

3.6.1 Drilling well control equipment, including auxiliary well control equipment, is to meet the requirements of the following main Standards and where applicable other standards referenced in Appendix A.

3.6.2 Consideration during the design of the well control system to reducing the risk to personnel during routine maintenance or operations is to be undertaken.

3.6.3 Where surface BOPs are being used, a risk assessment on the need for an SID (sea bed isolation device) is to be submitted to LR for review.

3.6.4 The number of components and arrangement for the blow out preventer stack is to be presented to LR for review:

API Spec 16A/ ISO 13533:2001	*Specification for drill-through equipment*.
API Spec 16C	*Specification for choke and kill systems*.
API RP 16D	*Control Systems for Drilling Well Control Equipment and Control Systems for Diverter Equipment*.
API Spec 16F	*Specification for marine drilling riser equipment*.
API RP 16Q	*Recommended practice for design, selection, operation and maintenance of marine drilling riser systems*.
API Spec 16R	*Specification for marine drilling riser couplings*.
API Spec 16RCD	*Specification for drill through equipment rotating control devices*.
API RP 16ST	*Coiled tubing well control equipment systems*.

API RP 53	*Blowout prevention equipment systems for drilling wells*.
API RP 59	*Recommended practices for well control operations*.
API RP 64	*Recommended practices for diverter systems equipment and operations*.

Section 4
Bulk storage wet and dry systems

4.1 General

4.1.1 The requirements for fired and unfired pressure vessels associated with the drilling plant and bulk storage vessels are to comply with the general requirements of Ch 8,4.

4.1.2 Pressure vessels are to comply with the design requirements in Ch 8,4.

4.1.3 Degasser and mud-gas separators are to be suitably constructed to handle the maximum design flow rate. All vented lines are to be of sufficient capacity and be vented to a safe location. Design particulars are to be submitted to LR for review.

4.1.4 Cementing units and associated high pressure pipes and manifolds are to be suitably designed and tested. If the cement unit is designed to be used as a kill unit, the components, specifications, capacities and power arrangements are to be supplied to LR for review.

4.1.5 The bulk system is to be designed to receive, store and deliver required volumes of bulk material to the mud and cementing system. Design capacities of the system are to be submitted for LR review.

4.1.6 Bulk storage vessels which penetrate watertight decks or flats are to be suitably reinforced, *see* Ch 3,2.10.

4.1.7 All bulk tanks, wet and dry, are to be designed for ease of cleaning and have adequate facilities for access and rescue of personnel.

4.2 Dry bulk systems

4.2.1 All dry bulk tanks are to be fitted with weight or volume indicators and a high level alarm. Provision for manual measurement is to also be made available.

4.2.2 The dry bulk vessels are to be designed for ease of cleaning and have adequate facilities for access and rescue of personnel.

4.2.3 All dry bulk lines (including ventilation lines) are to be designed for minimum flow resistance, minimum possible length and as few bends as possible. Connection points for purge air will be installed at critical flow areas in the bulk lines. Vent line outlets are to be kept as far as possible from HVAC inlets and normally manned areas.

4.2.4 The bulk air supply will be designed with redundancy and is to incorporate bulk air dryers. The compressors are to be located as close to the bulk storage tanks as possible.

4.2.5 The design is to prevent inadvertent mixing of cement and other bulk material.

4.2.6 All dry bulk storage vessels are to be equipped with safety valves or bursting discs to prevent damage due to overpressure. Bursting discs may only be used for vessels located in open areas or, if fitted in conjunction with a relief line, the discharge must be led to an open area.

4.2.7 For dry bulk storage vessels in enclosed areas, testable full open safety valves which can be vented out of the area are to be used. The enclosed areas where bulk storage vessels are located are to be ventilated such that a build-up of pressure will not occur in the event of a break or leak in the air supply system.

4.3 Wet bulk systems

4.3.1 Wet bulk storage tanks are to be suitably constructed with regard to the design maximum mud weight capacity of the vessel. All tanks are to be suitably equipped with equipment for preventing settling of mud.

4.3.2 The system will incorporate transfer systems with dedicated redundancy of pumps and manifolds. Sufficient by-passes with necessary valves for the liquid bulk in each storage tank are required. The systems are to be designed to transfer the relevant liquid bulk of design-specified weight and capacity to the liquid bulk tanks.

4.3.3 The design is to prevent inadvertent mixing of base oil and brine liquids.

4.3.4 High pressure mud pumps are to be fitted with pulsation dampers and relief valves set at the maximum allowable pressure of the system.

4.3.5 The mud pump relief line from the safety valve is to be self-draining and be as direct as possible with no bends and be suitably secured. The relief line after the relief valve is to be the same pressure rating as the pressure line before the relief valve. Facilities for flushing the vent lines are to be incorporated.

4.4 Mud mixing and storage system

4.4.1 The mud mixing and storage system is to be designed with sufficient capacity and structural strength to perform all planned mud mixing and storage operations with minimum risk of spillage or release of dust or fumes.

4.4.2 The entire mixing and storage system is to be designed for safe material handling and protection for personnel and the environment.

4.5 Mud treatment system

4.5.1 The mud treatment system is to be designed to operate without any risk to personnel with regard to spillage or exposure to hazardous substances.

■ *Section 5*
Offshore safety and pollution

Dutyholders are to meet the requirements of the following main Standards and, where applicable, other standards referenced in Appendix A., or equivalent, as a minimum to ensure adequate safety to personnel and the environment.

API Spec 14A/ ISO 10432:2004	*Specification for subsurface safety valve equipment.*
API RP 14B/ ISO 10417:2004	*Recommended practice for design, installation, repair and operation of subsurface safety valve systems.*
API RP 14C	*Recommended practice for analysis, design, installation and testing of basic surface safety systems on offshore production platforms*.
API RP 14E	*Recommended practice for design and installation of offshore production platform piping systems*.
API RP 14F	*Recommended practice for design and installation of electrical systems for fixed and floating offshore petroleum facilities for unclassified and class I, division 1, and division 2 locations*.
API RP 14FZ	*Recommended practice for design and installation of electrical systems for fixed and floating offshore petroleum facilities for unclassified and class I, zone 0, zone 1, and zone 2 locations*.
API RP 14G	*Recommended practice for fire prevention and control on fixed open type offshore production platforms*.
API RP 14J	*Recommended practice for design and hazards analysis for offshore production facilities*.
API RP 49	*Recommended practice for drilling and well servicing operations involving hydrogen sulfide*.
API RP 54	*Recommended practice for occupational safety and health for oil and gas well drilling and servicing operations.*
API Std 2000	*Venting atmospheric and low-pressure storage tanks*.
API RP 76	*Contractor safety management for oil and gas drilling and production operations*.
API RP 75	*Recommended practices for development of a safety and environmental management program for offshore operations and facilities*.

■ *Section 6*
Competence

Dutyholders are to ensure all their personnel are suitably trained and assessed with regard to their competence in performing their routine work and also with regard to emergency drills and duties.

■ *Section 7*
Electrical installations

7.1 General

7.1.1 In general, electrical installations are to comply with the requirements of Pt 6, Ch 2.

7.1.2 Electrical equipment installed in areas where an explosive gas atmosphere may be present is to be in accordance with Pt 7, Ch 2 and Section 9 or an equivalent standard acceptable to LR.

■ *Section 8*
Control systems

8.1 General

8.1.1 In general, control engineering systems are to comply with the requirements of Pt 6, Ch 1 and/or with the appropriate Codes or Standards defined in Appendix A, as applicable.

8.1.2 The control aspects of the blow out preventer stack are to be in accordance with the requirements of 3.6.

8.1.3 Emergency shut-down systems and other safety and communication systems are to comply with the requirements of Pt 7, Ch 1.

■ *Section 9*
Fire, hazardous areas and ventilation

9.1 General

9.1.1 Hazardous areas and ventilation are to comply with Ch 3,3 and Pt 7, Ch 2.

9.1.2 The general requirements for fire safety are to comply with Pt 7, Ch 3.

9.1.3 A general arrangement drawing(s) of the unit, showing hazardous zones and spaces as well as the design philosophy is to be submitted to LR for review. The drawing is to refer to the requirements of Pt 7, Ch 2 and equivalent standards, for example:

API RP 14F	*Recommended practice for design and installation of electrical systems for fixed and floating offshore petroleum facilities for unclassified and class I, division 1, and division 2 locations*.
API RP 14FZ	*Recommended practice for design and installation of electrical systems for fixed and floating offshore petroleum facilities for unclassified and class I, zone 0, zone 1, and zone 2 locations*.
API RP 505	*Recommended practice for classification of locations for electrical installations at petroleum facilities classified as class 1, zone 0, zone 1, and zone 2*.
API RP 500	*Recommended practice for classification of locations for electrical installation at petroleum facilities classified as class 1, division 1 and division 2*.

IP Model code P15.

■ *Section 10*
Risks to personnel from dropped objects

10.1 Goal

10.1.1 The requirements of this Section are to ensure that risks to personnel from dropped objects, hereinafter referred to as DROPS, are continuously addressed, in so far as they affect the objectives of classification.

10.2 Class notation

10.2.1 Where the requirements of this Section are met to the satisfaction of LR, units will be eligible to be assigned the **DROPS** class notation. This notation will be retained as long as the preventive measures to protect personnel from hazards from dropped objects are found, upon examination at the prescribed surveys, to be maintained to the satisfaction of LR.

10.3 Scope

10.3.1 Each unit is required to have a DROPS management system in place and be relevant to the design and specifics of the unit.

10.3.2 The Builder or Owner will create a general arrangement drawing of critical DROPS areas which will be clearly displayed in general information areas throughout the unit and accommodation.

10.3.3 The DROPS GA drawing will identify each area with colour coding and will clearly indicate the criticality levels within areas of the unit. The colour criticality coding is to be assigned as follows:

(a) Green Zone:
Where the layout and activities of the area present little likelihood of personnel being exposed to potential dropped objects under normal circumstances.

(b) Yellow Zone:
Where the layout and activities of the area present some risk of personnel being exposed to potential dropped objects under normal circumstances.

(c) Red Zone:
Where the layout and activities of the area present significant risk of personnel being exposed to potential dropped objects under normal circumstances.

10.3.4 Zones are to be clearly displayed at all access points to the respective areas. All signs are to be pictorial to eliminate potential issues with different languages. Refer to BS EN IEC 62079:2001 Section 4.7.3.2 for further information.

10.3.5 All third party equipment, permanent or temporary, is to undergo a design risk assessment before installation. Records and methods of inspecting the third party equipment are to be maintained and available for LR review.

10.3.6 Suitable equipment and hand tools for working at height are to be provided. Details and records of inspection of such tools and equipment are to be maintained and available for LR review.

10.3.7 When the use of DROPS shelters are incorporated into the safety management system, full structural and installation details of the shelters, including the intended level of safety, are to be presented for LR review.

10.3.8 The preventive maintenance systems of the unit are to indicate where specialised work at height tooling is required for routine maintenance.

10.3.9 An inventory of permanent fixed equipment is to be created and maintained by the unit; the inventory is to include photographs and a description of each item. The photographs are to be taken from a distance and also from close up to avoid confusion with identification. Each individual item of equipment is to be identified by permanent marking or by the use of suitably attached durable labels.

10.3.10 An inventory of temporarily installed equipment is to be created and maintained by the unit. This will incorporate scheduled routine inspections to verify that no modifications, changes or damage to the equipment has occurred since the initial inspection on installation, or previous scheduled inspection.

10.3.11 A program of scheduled surveys and inspection will be created; methods and records of inspection and any remedial actions are to be maintained and available for LR review.

10.3.12 A record of failed items, with reason for failure, is to be maintained and is to be available for review by LR.

■ *Section 11* **Trials**

11.1 General

11.1.1 Before a new drilling plant (or any alteration or addition to an existing plant) is put into service, final drilling plant trials are to be carried out by an approved technical organisation, as defined in 11.2, to demonstrate that the integral drilling plant is suitable for safe operation and can operate as per the design.

11.1.2 The operational philosophy of the drilling plant is to be submitted for consideration. The operational philosophy is to include:
(a) each task to be performed, e.g., drilling operations, equipment inspection/maintenance, cleaning and instrument observation;
(b) a robust identification of the hazards associated with each task;
(c) the methods used to manage the identified hazards.

11.1.3 Where the operational aspects of the drilling plant have an effect on the overall safety of the drilling unit, the personnel on board or the environment, these aspects are to be to the satisfaction of LR.

11.1.4 The final drilling plant trials are in addition to any acceptance tests which may have been carried out at the manufacturers' works and are to be based on an approved test schedule. The test schedule is to be submitted to LR for approval.

11.2 Approved technical organisation

11.2.1 An approved technical organisation, for the purposes of this Section, is one that can demonstrate that the trials are witnessed by competent experienced personnel with a minimum of 10 years' offshore operational drilling plant experience. CVs are to be submitted to LR for review. The approved technical organisation is to be acceptable to the Owner and LR.

Section

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter apply to the process plant facility on board production and oil storage units as defined in Chapter 3. The process plant facility includes the equipment and supporting structure and systems used for oil and gas production including separation, treating and processing systems and equipment and systems used in support of production operations. The requirements of this Chapter are considered to be supplementary to the requirements in the relevant Parts of the Rules.

1.1.2 The Rules cover the design strength and safety aspects of the process plant facility installed on board production and oil storage units.

1.1.3 The operational aspects and reliability of the production and process plant facility are not covered by class except when they have an effect on the overall safety of the production unit, the personnel on board or the environment.

1.1.4 The Rules are framed on the understanding that a unit with an installed production and process plant facility will not be operated in environmental conditions more severe than those for the design basis and class approval.

1.1.5 It is the responsibility of the Owners/Operators to ensure that the production and process plant facility is properly maintained and operated by qualified personnel and that the test and operational procedures are clearly defined and complied with.

1.1.6 The limiting design criteria on which approval is based are to be stated in the unit's Operations Manual.

1.2 Class notations

1.2.1 The Regulations for classification and the assignment of class notations are given in Pt 1, Ch 2, to which reference should be made.

1.2.2 Production units with an installed process plant facility which comply with the requirements of this Chapter, or recognised Codes and Standards agreed with LR, will be eligible for the assignment of the special features class notation **PPF**.

1.2.3 When a production unit is to be verified in accordance with the Regulations of a Coastal State Authority, an additional descriptive note may be assigned in accordance with Pt 1, Ch 2.

1.3 Scope

1.3.1 The following additional topics applicable to the special features class notation are covered by this Chapter:

- Major equipment and structures of the production and process plant.
- Oil or gas processing system, including flowlines from the riser termination flanges, manifolds, production swivels, separators, heaters and coolers, relief and blow-down systems and water treatment systems.
- Production plant safety systems.
- Production plant utility systems.
- Riser compensating and tensioning system.
- Relief and flare system.
- Well control system.

1.3.2 Unless agreed otherwise with LR the Rules consider the following as the main boundaries of the production and process plant facility:

- Any part of the production and process system located on the unit including the riser connecter valve or christmas tree but excluding the risers is considered part of the facility.
- The shut-down valve at the export outlet from the production or process plant to the storage or offloading facility.
- The outlet from hydrocarbon flare and vent system.

1.4 Plant design characteristics

1.4.1 The design and arrangements of the process plant are to comply with the requirements of this Chapter and with recognised Codes and Standards, *see* 1.5.

1.4.2 Attention is to be given to the relevant Statutory Regulations of the National Administration in the country of registration and the area of operation, as applicable.

1.4.3 The plant and supporting structures above the deck are to be designed for all operating and transit conditions in accordance with recognised and agreed Codes or Standards, suitably modified to take into account the unit's motions and marine environmental aspects. Except for the emergency condition, as detailed in 1.4.4, the total stress in any component of the plant is not to exceed the Code value at the temperature concerned, unless expressly agreed otherwise by LR, whether the plant is operative or non-operative, when subjected to any possible combination of the following loads, as applicable:

(a) Static and dynamic loads due to wave-induced unit motions.
(b) Loads resulting from hull flexural effects at the plant support points, as appropriate.
(c) Direct wind loads.
(d) Normal gravity and functional loads.
(e) Thermal loads, as appropriate.
(f) Ice and snow loads, as appropriate.

1.4.4 In general, the plant and supporting structures above the deck are to be designed for an emergency static condition with the unit inclined to the following angle:

- Column-stabilised units:
  25° in any direction.
- Surface type units:
  22,5° heel, port and starboard, and trimmed to an angle of 10° beyond the maximum normal operating trim.
- Self-elevating units:
  17° in any direction in transit conditions only.

These angles may be modified by LR in particular cases as considered necessary. In no case is the inclined angle for the emergency static condition to be taken less than the maximum calculated angle in the worst damage condition in accordance with the appropriate damage stability criteria.

1.4.5 In the emergency condition defined in 1.4.4, the plant is to be assumed to have maximum operating weights, temperatures and pressures unless agreed otherwise with LR. When applicable, the plant is also to be subjected to ice and snow loads. Wind loads need not be considered to be acting during this emergency condition. The total stress in any component of the plant or support structure above the deck is not to exceed the minimum yield stress of the material.

1.4.6 The permissible stresses in the primary hull structure below plant and equipment supports are to be in accordance with Pt 4, Ch 5.

1.5 Recognised Codes and Standards

1.5.1 Installed process plant facility designed and constructed to standards other than the Rule requirements will be considered for classification, subject to the alternative standards being agreed by LR to give an equivalent level of safety to the Rule requirements. It is essential that in such cases LR is informed of the Owner's proposals at an early stage in order that a basis for acceptance of the standards may be agreed. *See* Appendix A for applicable international Codes and Standards considered by LR as an equivalent level of safety to Rule requirements.

1.5.2 In general, the requirements in this Chapter are based on internationally recognised Codes and Standards for the production and process plant as defined in Appendix A. Other Codes and National Standards may be used after special consideration and prior agreement with LR. When considered necessary, additional Rule requirements are also stated in this Chapter.

1.5.3 Where necessary, the Codes are to be suitably modified and/or adapted to take into account all marine environmental aspects.

1.5.4 The agreed Codes and Standards may be used for design, construction and installation but where considered applicable by LR, compliance with the additional requirements stated in the Rules is required. Where there is any conflict the Rules will take precedence over the Codes or Standards.

1.5.5 The mixing of Codes or Standards for each equipment item or system is to be avoided. Deviation from the Code or Standard must be specially noted in the documentation and approved by LR.

1.6 Equipment categories

1.6.1 The approval and certification of production and process plant equipment are to be based on equipment categories agreed with LR.

1.6.2 Production and process plant equipment including its associated pipes and valves is to be divided into equipment Categories **1A**, **1B** and **II,** depending on the complexity of manufacture and its importance with regard to the safety of personnel and the installation and the possible effect on the environment.

1.6.3 The following equipment categories are used in the Rules:

1A Equipment of primary importance to safety, for which design verification and survey during fabrication are considered essential. Equipment in this category is of complicated design/manufacture and is not normally mass produced.

1B Equipment of primary importance to safety for which design verification and witnessing the product quality are considered essential. Equipment in this category is normally mass produced and not included in category **1A**.

II Equipment related to safety which is normally manufactured to recognised Codes and Standards and has proven reliability in service but excludes equipment in category **1A** and **1B**.

1.6.4 A guide to equipment and categories is given in Appendix A. A full list of equipment categories for each production and process plant facility is to be agreed with LR before manufacture. Minor equipment components need not be categorised.

1.7 Equipment certification

1.7.1 Equipment is to be certified in accordance with the following requirements:

(a) **Category 1A**
- Design verification and issue of certificate of design strength approval.
- Pre-inspection meeting at the suppliers with agreement and marking of quality plan and inspection schedule.
- Survey during fabrication and review of fabrication documentation.
- Final inspection with monitoring of function/ pressure/load tests and issue of a certificate of conformity.

(b) **Category 1B**
- Design verification and issue of certificate of design strength approval, where applicable, and review of fabrication documentation.
- Final inspection with monitoring of function/ pressure/load tests and issue of certificate of conformity.

(c) **Category II**
- Supplier's/manufacturer's works certificate giving equipment data, limitations with regard to the use of the equipment and the supplier's/manufacturer's declaration that the equipment is designed and fabricated in accordance with recognised Standards or Codes.

1.7.2 All equipment recognised as being of importance for the safety of personnel and the production and process plant facility is to be documented by a data book.

1.8 Fabrication records

1.8.1 Fabrication records are to be made available for Categories **1A** and **1B** equipment for inspection and acceptance by LR Surveyors. These records should include the following:
- Manufacturer's statement of compliance.
- Reference to design specification and plans.
- Traceability of materials.
- Welding procedure tests and welders' qualifications.
- Heat treatment records.
- Records/details of non-destructive examinations.
- Load, pressure and functional test reports.

1.9 Installation of plant equipment

1.9.1 The installation of equipment on board the unit is to be controlled by LR in accordance with the following principles:
- All Category **1A** and **1B** equipment delivered to the unit is to be accompanied by a certificate of design strength approval and an equipment certificate of conformity and all other necessary documentation.
- All Category **II** equipment delivered to the unit is to be accompanied by equipment data and a works' certificate.
- Control and follow-up of non-conformities/deviations specified in design certificates and certificate of conformity.
- Ongoing survey and final inspection of the installed production and process plant.
- Monitoring of functional tests after installation on board in accordance with an approved test programme.
- Issue of a plant installation report.

1.10 Maintenance and repair

1.10.1 It is the Owner's/Operator's responsibility to ensure that installed production and process plant is maintained in a safe and efficient working condition in accordance with the manufacturer's specification.

1.10.2 When it is necessary to repair or replace installed production and process plant, any repaired or spare part is to be subject to the equivalent certification as the original.

1.11 Plans and data submissions

1.11.1 Plans, calculations and data are to be submitted as required by the relevant Parts of the Rules together with the additional plans and information listed in this Chapter. Plans are to be submitted in triplicate, but only a single copy of supporting documents and calculations is required.

■ *Section 2* Structure

2.1 Plans and data submissions

2.1.1 The following additional plans and information are to be submitted:
- General arrangement plans of the plant layout.
- Plans and design calculations as required for derricks in Ch 7,2, when appropriate.
- Structural plans of equipment skids and design calculations.
- Structural plans of equipment support frames and trusses and design calculations.
- Flare structures and design calculations.

2.2 Materials

2.2.1 Materials are to comply with Ch 1,4 and material grades are to comply with Pt 4, Ch 2 using the categories defined in this Section.

2.2.2 Support structures for the production and process plant are to be divided into the following categories:
- Primary structure.
- Secondary structure.

2.2.3 Some specific examples of structural elements which are considered as primary structure are as follows:

- Module main frame members and deck support stools.
- Main legs and chords including end connections.
- Foundation bolts.

2.3 Miscellaneous structures

2.3.1 The design loadings for all structures supporting plant, including equipment skids, support frames and trusses, are to be defined by the designers/Builders and calculations are to be submitted in accordance with an appropriate Code or Standard, *see* Appendix A. The design requirements of 1.4 are to be complied with.

2.3.2 The design of process plant support structures should integrate with the primary hull under-deck structure.

2.3.3 The permissible stresses in the hull structure below the production and process plant are to be in accordance with Ch 3,2 and Pt 4, Ch 5,2.

2.4 Flare structures

2.4.1 Flare structures are to be designed for an emergency condition and for normal operating conditions as defined in 1.4 and in accordance with an appropriate Code or Standard, *see* Appendix A.

2.4.2 The flare structures are also to be designed for the imposed loads due to handling the structure and when in the stowed position.

2.4.3 The designers/Builders are to specify the maximum weight of the burner and spreader and the design criteria defined in 1.4.

2.4.4 The structural design of flare structures is to include the effect of fatigue loading and the thermal loads during flaring, *see* Pt 4, Ch 5.

2.4.5 Where National Administrations give specific requirements with respect to fatigue design, it is the responsibility of the Owners to comply with such Regulations.

2.4.6 For slender structures and components, the effects of wind induced cross-flow vortex vibrations are to be assessed.

2.4.7 Wind loads are to be calculated in accordance with LR's *Code for Lifting Appliances in a Marine Environment* (hereinafter referred to as LAME Code) or a recognised Code or Standard, *see* Appendix A.

2.4.8 Permissible stresses in the hull structure below the flare structure supports are to be in accordance with Pt 4, Ch 5.

2.5 Lifting appliances

2.5.1 Lifting appliances used for handling flare structures and blow out preventers are to be in accordance with LR's LAME Code, *see also* Chapter 11.

2.6 Guard rails and ladders

2.6.1 It is the Owners' responsibility to provide permanent access arrangements and protection by means of ladders and guard rails. It is recommended that such arrangements are designed in accordance with a recognised Code or Standard.

■ *Section 3* Production, process and utility systems

3.1 Plans and particulars

3.1.1 Plans and particulars showing arrangement of production, process and utility systems and equipment listed in 1.3, and diagrammatic plans of the associated piping systems, are to be submitted for approval.

3.2 General requirements for piping systems

3.2.1 The design and construction of the piping systems, piping and fittings forming parts of such systems are to be in accordance with a recognised Code or Standard, *see* 1.5, and are also to comply with the remainder of this Section.

3.2.2 Piping systems for the production and process plant are, in general, to be separate and distinct from piping systems essential to the safety of the unit. Notwithstanding this requirement, this does not exclude the use of the unit's main, auxiliary and/or essential services for process plant operations in suitable cases. Attention is drawn to the relevant Chapters of Part 5, Main and Auxiliary Machinery, when such services are to be utilised. Substances which are known to present a hazard due to a reaction when mixed are to be kept entirely separate.

3.2.3 All piping systems are to be suitable for the service intended and for the maximum pressures and temperatures to which they are likely to be subjected.

3.2.4 The number of detachable pipe connections in hydrocarbon production and process piping is to be limited to those which are necessary for installation and dismantling. The pipe connections are to be suitable for the intended use.

3.2.5 Soft-seated valves and fittings which incorporate elastomeric sealing materials installed in systems containing hydrocarbons or other flammable fluids are to be of a fire-tested type.

3.2.6 The production and process system piping is to be protected from the effects of fire, mechanical damage, erosion and corrosion. Corrosion coupons or test spool pieces are to be designed into the system. Spool pieces are to be fitted in such a manner as to be easily removed or replaced. Sand probes and filters should be provided where necessary for extraction of sand or reservoir fracture particles.

3.2.7 The corrosion allowance for hydrocarbon production and process piping of carbon steel is not to be less than 2 mm.

3.2.8 Piping for services essential to the production and process operations, and piping containing hydrocarbon or other hazardous fluids is to be of steel or other approved metallic construction. Piping material for H_2S-contaminated products (sour service) is to comply with the NACE MR0175/ISO15156 - *Petroleum and Natural Gas Industries – Materials for use in H_2S-containing Environments in Oil and Gas Production*, *see* Appendix A.

3.2.9 Arrangements are to be made to isolate the unit from the supply and discharge of produced oil and gas by the provision of suitable shut-down valves on the unit and at the receiving installation. The valves on board the unit are to be operable from the control stations as well as locally at the valve.

3.2.10 If a single failure in the supply from utility systems such as compressed air or cooling water which are essential to the operation of the production and process plant could cause an unacceptable operating condition to arise, an alternative source of supply is to be provided.

3.2.11 Process vessel washout connections are to be fitted with non-return valves in addition to the shut-off valves.

3.2.12 The locking open/closed of valves is to be by means of a suitable keyed locking device operated under a permit-to-work system.

3.2.13 For process vessels which periodically require isolation prior to gas-freeing and personnel entry, pipelines which connect the vessel to a source of pressure and/or hazardous fluid are to be provided with isolating valves, bleed arrangements and means to blank off the open end of the pipe. For systems containing significant hazards, consideration is to be given to double block and bleed valves and blanking-off arrangements.

3.2.14 For surface type units, the design of piping systems should take into consideration the effect of hull girder bending.

3.3 Flexible piping

3.3.1 Flexible piping elements approved for their intended use may be installed in locations where rigid piping is unsuitable or impracticable. Such flexible elements are to be accessible for inspection and replacement, and are to be secured and protected so that personnel will not be injured in the event of failure.

3.3.2 Short lengths of flexible hose may be utilised to allow for limited misalignment or relative movement. All flexible hoses are to be manufactured to a recognised Code or Standard, and a prototype hose with end fittings attached is to have been burst-tested to the minimum pressure stipulated by the appropriate standard. Protection against mechanical damage is to be provided where necessary.

3.3.3 Means are to be provided to isolate flexible hoses if used in systems where uncontrolled outflow would be critical.

3.4 Christmas tree

3.4.1 The christmas tree is to have at least one remotely-operated, self-closing master valve and a corresponding wing valve for each penetration of the tree. In addition, there is to be a closing device for each penetration at a level higher than the wing outlets.

3.4.2 Additional wing outlets such as injection lines are to penetrate the christmas tree above the lowest remotely-operated master valve, and be fitted with a remotely-operated, self-closing control valve and a check valve installed as close as possible to the injection point. The injection point for hydrate inhibitor may be fitted below the lowest self-closing master valve if the christmas tree is fitted with valve(s) below this point.

3.4.3 All valves in the vertical penetrations of the christmas tree are to be capable of being opened and kept in the open position by means of an external operational facility independent of the primary actuator.

3.4.4 Valves that are important in connection with the emergency shut-down system such as the master and wing valves are to be fitted locally with visual position indicators.

3.4.5 Where exposure to H_2S-contaminated products is likely, materials and welds shall meet the requirements of the NACE MR0175/ISO15156 – *Petroleum and Natural Gas Industries – Materials for use in H_2S-containing Environments in Oil and Gas Production*.

3.5 Protective pressure relief

3.5.1 Process vessels, equipment and piping are to be provided with pressure-relieving devices to protect against system pressures exceeding the maximum allowable pressure such that the system will remain safe under all foreseeable conditions, unless the system is designed to withstand the maximum pressure which can be exerted on it under any circumstances. Where appropriate, sections of the production and process system are to be protected against underpressure resulting from a change of temperature or state of the contents, *see also* 4.9.

3.5.2 The pressure-relieving devices are to be sized to handle the expected maximum relieving rates due to any single failure or fire incident. The rated discharge capacity of any pressure-relieving device is to take into account the back pressure in the vent system.

3.5.3 For protected items or sections of the system not in continuous service, a single pressure-relieving device is acceptable. Block valves for maintenance purposes, where fitted, in the pressure relief lines are to be interlocked with the source of pressure or spare relief valves as applicable.

3.5.4 For any particular item or section of the system in continuous service at least two pressure relief possibilities are to be provided for operational and maintenance purposes. In this case, each pressure relief possibility is to be designed to handle 100 per cent of the maximum relieving rate expected unless alternative systems are available or short-term shut-down is acceptable.

3.5.5 If more than two pressure relief possibilities are provided on any particular item or section of the system in continuous service, and any pressure relief possibility is designed to handle less than 100 per cent of the maximum relieving rate expected, the arrangements are to be such as to allow any one device to be isolated for operational and maintenance purposes without reducing the capacity of the remaining devices below 100 per cent of the maximum relieving rate.

3.5.6 Block valves fitted in pressure relief lines for isolation purposes are to be of the full-flow type, capable of being locked in the fully open position by an approved keyed method.

3.5.7 The arrangement in 3.5.4 or 3.5.5 is to ensure that all relief possibilities cannot be isolated from the system at the same time, by interlocking the block valves using an approved keyed method of interlocking operated under a permit-to-work system.

3.5.8 The set pressure for all pressure-relieving devices should generally not exceed the design pressure of the protected system or item. Pressure relief valves are to be sized such that any accumulation of pressure from any source will not exceed 110 per cent of the design pressure.

3.5.9 Bursting discs fitted in place of, or in series with, a pressure relief valve are to be rated to rupture at a pressure not exceeding the design pressure of the protected system or item. However, in the case of a bursting disc fitted in parallel with a relief valve(s), such as in vessels containing substances which may render a pressure relief valve inoperative or where rapid rates of pressure rise may be encountered, the bursting disc is to be rated to burst at a maximum pressure not exceeding 1,3 times the design pressure of the vessel at the operating temperature.

3.5.10 Pressure-relieving devices are normally to be connected to the flare and relief header to minimise the escape of hydrocarbon fluids, and to ensure their safe collection and disposal. Where appropriate, vent and discharge piping arrangements are to be such as to avoid the possibility of a hazardous reaction between any of the fluids involved.

3.5.11 In circumstances where hazardous vapours are released directly to the atmosphere, the outlets are to be arranged to vent to a safe location where personnel would not be endangered.

3.5.12 The inlet piping to a pressure relief device should be sized so that the pressure drop from the protected item to the pressure relief device inlet flange does not exceed three per cent of the device set pressure.

3.5.13 Pressure-relieving devices and all associated inlet and discharge piping are to be self-draining. Open vents are to be protected against ingress of rain or foreign bodies.

3.5.14 Relief piping supports are to be designed to ensure that reaction forces during relief are not transmitted to the vessel or system, and to ensure that relief devices are not used as pipe supports or anchors where the resultant forces could interfere with the proper operation of the device.

3.5.15 The design and material selection of the pressure-relieving devices and associated piping is to take into consideration the resulting low temperature, vibration and noise when gas expands in the system.

3.5.16 Positive displacement pumps and compressors for hydrocarbon oil/gas service are to be provided with relief valves in closed circuit, set to operate at a pressure not exceeding the maximum allowable pressure of the pump or equipment connected to it, and adequately sized to ensure that the pump output can be relieved without exceeding the system's maximum allowable pressure. Proposed alternatives to relief valves may be considered and full details should be submitted.

3.5.17 Relief valves may also be required on the suction side of pumps and compressors when recycling from the discharge side is possible.

3.6 Flaring arrangements

3.6.1 Facilities for gas flaring and oil burning are to be adequate for the flaring requirements during well control, well testing and production operations. For well testing, at least two flare lines are to be arranged through which any flow from the well may be directed to different sides of the unit.

3.6.2 The flare system is to be designed to ensure a clean, continuous flame. Provision is to be made for the injection of make-up gas into the vent system to maintain steady flaring conditions. A means of cooling the flare burners when used for well testing is to be available.

3.6.3 The flare burners are to be located at a safe distance from the unit. This distance, or protection zone, is to be determined by consideration of the calculated thermal radiation levels. For limiting thermal radiation levels, *see* 3.9.

3.6.4 For well test systems, any flare line or other line downstream of the choke manifold is to have an inside diameter not less than the inside diameter of the largest line in the choke manifold.

3.6.5 Production and process plant venting systems are to be led to a liquid separator or knock-out drum to remove any entrained liquids which cannot be safely handled by the flare. Where a liquid blow-down system is provided, adequate provision is to be made in the design for the effects of back pressure in the system, and for vapour flash-off when the pressures in the blow-down system are reduced.

3.6.6 The flare system is to be capable of controlling any excess gas pressures resulting from emergency depressurising conditions.

3.7 Depressurising system

3.7.1 All production and process plant in which significant volumes of hydrocarbon liquids and gases with potential for incident escalation can be blocked in during a fire is to be capable of being depressurised. The capacity of the system should be based on evaluation of:

- system response time;
- heat input from defined accident scenarios;
- material properties and material utilisation ratio;
- other protection measures, e.g., active and passive fire protection;
- system integrity requirements.

3.7.2 The emergency depressurising system is to be designed to reduce pressures to a level to prevent rupture of the pressure-containing components. As a minimum requirement, the depressurising system is to be designed to ensure that the pressure is reduced to half the equipment's maximum allowable working pressure or 6.9 bar, whichever is lower, within approximately 15 minutes.

3.7.3 The cooling effect due to throttling of large volumes of high pressure gas in the discharge piping and valves during the depressurising period is to be evaluated for appropriate material selection. Where temperatures below minus 29°C are expected, the piping and valve material is to have specified average Charpy V-notch impact values of 27J minimum at the calculated lowest operational temperature.

3.7.4 The vent system design should ensure that allowance has been given to the possibility of high dynamic forces at pipe bends and supports during emergency depressurisation.

3.8 Cold vents

3.8.1 A cold vent is acceptable only if it is determined that the gas release will not create any danger to the unit. Due consideration should be given to the prevailing wind to ensure that gases do not flow down around operating areas. Where cold venting is provided, the arrangement is to minimise:

- Accumulation of toxic and flammable gases.
- Ignition of vent gases from outside sources.
- Flashback upon accidental ignition of the vent gases.

3.8.2 In order to avoid continuous burning of the vent gases in the case of accidental ignition, an extinguishing system using a suitable inert gas is to be installed.

3.8.3 The dew point of the gases is to be such that they will not condense at the minimum ambient temperature. In the case of liquid condensation in the cold vent piping, a drain or liquid collection system is to be provided to prevent accumulation of liquid in the vent line.

3.9 Radiation levels

3.9.1 The location and designed throughput of the flare is to take into consideration the levels of thermal radiation to ensure that exposure of personnel, structure and equipment is acceptable even under unfavourable wind conditions.

3.9.2 Under normal operating circumstances, the intensity of thermal radiation, including solar radiation, in unprotected areas where personnel may be continuously exposed is not to exceed 1,9 kW/m^2 in calm conditions. Allowance for the cooling effect of wind in unsheltered areas may be taken into consideration in determining the radiation levels.

3.9.3 Under emergency flaring conditions, the intensity of thermal radiation at muster stations and in areas where emergency actions of short duration may be required by personnel is not to exceed 4,7 kW/m^2 in calm conditions.

3.9.4 Suitable radiation screens, water screening or equivalent provision should be utilised to protect personnel, structure and equipment as necessary.

3.10 Firing arrangements for steam boilers, fired pressure vessels, heaters, etc.

3.10.1 The requirements of this Section are applicable to all types of fired equipment associated with the process plant. The equipment is to be constructed, installed and tested to the Surveyor's satisfaction.

3.10.2 Details of the design and construction of the fuel gas burning equipment for steam boilers, oil and gas heater furnaces, etc., are to be in accordance with agreed Codes, Standards and specifications normally used for similar plants in land installations, suitably modified and/or adapted for the marine environment. Ignition of the burners is to be by means of permanently installed igniters, or properly located and interlocked pilot burners and main burners arranged for sequential ignition.

3.10.3 Proposals to burn gas or gas/air mixtures having relative densities compared with air at the same temperature greater than one will be specially considered in each case. *See also* Pt 5, Ch 16.

3.10.4 Proposals for the furnace purging arrangements prior to ignition of the burners are to be submitted. Such arrangements are to ensure that any accidental leakage of product liquid or gas into the furnace, from a liquid or gas heating element, or from the accidental ingestion of flammable gases and/or vapours, does not result in hazardous conditions.

3.10.5 Compartments containing fired pressure vessels, heaters, etc., for heating or processing hazardous substances are to be arranged so that the compartment in which the fired equipment is installed is maintained at a higher pressure than the combustion chamber of the equipment. For this purpose, induced draft fans or a closed system of forced draught may be employed. Alternatively, the fired equipment may be enclosed in a pressurised air casing.

3.10.6 The fired equipment is to be suitably lagged. The clearance spaces between the fired equipment and any tanks containing oil are to be not less than 760 mm. The compartments in which the fired equipment is installed are to be provided with an efficient ventilating system.

3.10.7 Smoke box and header box doors of fired equipment are to be well fitted and shielded, and the uptake joints made gastight. Where it is proposed to install dampers in the uptake gas passages of fired equipment, the details are to be submitted. Dampers are to be provided with a suitable device whereby they may be securely locked in the fully open position.

3.10.8 Each item of fired equipment is to have a separate uptake to the top of the stack casing. Where it is proposed to install process fired equipment with separately fixed furnaces converging into a convection section common to two or more furnaces and/or a secondary radiant section at the confluence of the fired furnace uptake to the convection section, the proposed arrangements, together with the details of the furnace purging and combustion controls, are to be submitted.

3.11 Drain systems

3.11.1 Drainage systems are to be provided to collect and direct drained or escaped liquids to a location where they can be safely handled or stored. In general, equipment is to be provided with a hard-piped, closed drainage system for small quantities of produced liquids, an open system handling drainage from hazardous areas, and an open system handling drainage from non-hazardous areas. These systems are to be entirely separate and distinct.

3.11.2 The hazardous drainage systems are to be kept separate and distinct from those of the main and auxiliary machinery systems. Consideration will be given to directing the process facilities hazardous drains to the facilities oil storage tanks. The hazardous drains fluids should not be allowed to free-fall into the tank. In units equipped with an inert gas system, a U-seal of adequate height, or equivalent method, should be arranged in the piping leading to the oil storage tanks.

3.11.3 Provision is to be made for protection against over-pressurisation of a lower pressure drainage system when connected to a higher pressure system.

3.12 Bilge and effluent arrangements

3.12.1 Where, during operation, the production plant spaces contain, or are likely to contain, hazardous and/or toxic substances, they are to be kept separate and distinct from the unit's main bilge pumping system. This does not, however, preclude the use of the unit's main bilge system when the production plant is shut down, gas freed or otherwise made safe.

3.12.2 The bilge and effluent pumping systems handling hazardous and/or toxic substances should, wherever possible, be installed in the space associated with the particular hazard. Spaces containing pumping systems that take their suctions from a hazardous space will also be designated as hazardous spaces unless all associated pipelines are of all-welded construction without flanges, valve glands and bolted connections, and the pump is totally enclosed.

3.12.3 Bilge and effluent piping systems related to the production plant are to be constructed of materials suitable for the substances handled, including any accidental admixture of such substances.

3.12.4 Arrangements are to be provided for the control of the bilge and effluent pumping systems installed in production and process plant spaces from within the spaces and from a position outside the spaces.

■ *Section 4*
Pressure vessels and bulk storage

4.1 General

4.1.1 The Rules in this Section are applicable to fired and unfired pressure vessels associated with process plant, and drilling plant defined in Chapter 7.

4.1.2 Pressure vessels are to be designed in accordance with Pt 5, Ch 10 and Ch 11 or with internationally recognised and agreed Codes and Standards and in accordance with the requirements of Section 1.

4.1.3 The list in Appendix A, A 1.2.11 gives reference to some generally recognised Codes and Standards frequently specified for drilling and production equipment. These Codes and Standards may be used for certification but the additional requirements given in the Rules apply and the Rules will take precedence over the Codes and Standards wherever conflict occurs.

4.1.4 Portable gas cylinders and other pressure vessels used to transport liquids or gases under pressure are to comply with an acceptable National or International Standard.

4.1.5 Where pressure parts are of such an irregular shape that it is impracticable to design their scantlings by the application of recognised formulae, the acceptability of their construction is to be determined by hydraulic proof testing and strain gauging or by an agreed alternative method.

4.2 Plans and data submissions

4.2.1 Design documentation is to be submitted for all pressure vessels.

4.2.2 The submitted information is to include the following:

- Design specification, including data of working medium and pressures.
- Minimum/maximum temperatures, corrosion allowance, environmental and external loads.
- Plans, including sufficient detail and dimensions to evaluate the design.
- Strength calculations for normal operating and emergency conditions.
- Bill of Materials including material specifications as necessary.
- Fabrication specifications including welding, heat treatment, type and extent of NDE.

4.3 Equipment certification

4.3.1 Equipment certification is to be carried out in accordance with Section 1 and equipment categories are to comply with Table A 2.3 in Appendix A.

4.4 Materials

4.4.1 Materials for pressure vessels are to comply with Ch 1,4 and the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials), except where modified by this Section.

4.4.2 Welded carbon/manganese (C–Mn) steels used for major pressure containing parts should have a chemical composition limited by the carbon content and the carbon equivalent:

Carbon content $C \leq 0,25$

When the elements in the following formula are known, this formula is to be used:

Carbon Equivalent:

$$CE = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15} \leq 0,45$$

Symbols are as defined in the Rules for Materials.

4.4.3 The use of material not meeting these limitations is subject to special consideration in each case. The welding of such materials normally requires more stringent fabrication procedures regarding the selection of consumables, preheating and post weld heat treatment.

4.4.4 Materials for pressure containing parts are to be tested at the temperature specified in Table 13.4.1 in Chapter 13 of the Rules for Materials and shall achieve a minimum energy of 27J for materials with specified minimum yield strength less than or equal to 360 MPa and 42J for higher strength materials.

4.4.5 Equipment and components required for hydrogen sulphide sour service shall meet the property requirements of NACE MR0175/ISO15156 – *Petroleum and Natural Gas Industries – Materials for use in H_2S-containing Environments in Oil and Gas Production*.

4.5 Design pressure and temperature

4.5.1 The design pressure is the maximum permissible working pressure and is not to be less than the highest set pressure of the safety valve. If the design of the system is such that it may be possible for it to see a vacuum, the design pressure shall also consider the minimum working pressure which the system may see.

4.5.2 The calculations made to determine the scantlings of the pressure parts are to be based on the design pressure, adjusted where necessary to take account of pressure variations corresponding to the most severe operating conditions.

4.5.3 It is desirable that there should be a margin between the normal pressure at which the pressure vessel operates and the lowest pressure at which any safety valve is set to lift, to prevent unnecessary lifting of the safety valve.

4.5.4 The design temperature, T, used to evaluate the allowable stress, σ, is to be taken as the actual mean wall metal temperature expected under operating conditions for the pressure part concerned, and is to be stated by the manufacturer when the plans of the pressure part are being considered. For fired steam boilers, T is to be taken as not less than 250°C.

4.6 Design safety factors

4.6.1 The term 'allowable stress', σ, is the stress to be used in the formulae for calculating the scantlings of pressure vessels.

4.6.2 The allowable stress used for the design of a pressure vessel is to be in accordance with the Code or Standard being used to design that vessel.

4.6.3 Pressure vessels are to be designed for the emergency conditions referred to in 1.4.

4.6.4 It is not permissible to use the allowable stress levels of one Code or Standard to determine the scantlings using the formulae from a different Code or Standard.

4.6.5 The yield strength used in the determination of allowable stress or in calculations is not to exceed 0,85 of the specified minimum tensile strength of the material in question.

4.7 Construction and testing

4.7.1 Fabrication documentation is to be compiled by the manufacturer simultaneously with the fabrication in a systematic and traceable manner so that all the information regarding the design specification, materials, fabrication processes, inspection, heat treatment, etc., can be readily examined by the Surveyor.

4.7.2 Welding procedures and construction requirements for welding shall be in accordance with those specified in Chapters 12 and 13 of the Rules for Materials.

4.7.3 Procedures for performing non-destructive examination and the acceptance criteria to be applied shall be in accordance with the Chapter 13 of the Rules for Materials.

4.8 Hydrostatic test pressure

4.8.1 Pressure vessels are to be subject to a hydrostatic test in accordance with the applied Code, Standard, or specification before being taken into service.

4.8.2 The hydrostatic test pressure is to be a minimum of 1,5 x design pressure if not specified in the Code or Standard.

4.8.3 The pressure and holding time are to be recorded.

4.8.4 Primary general membrane stresses are in no case to exceed 90 per cent of the minimum yield strength of the material.

4.9 Protective and pressure relief devices

4.9.1 Pressure vessels are to be provided with protective devices so that they remain safe under all foreseeable conditions.

4.9.2 Where pumps and pressure surges are capable of developing pressures exceeding the design conditions of the system, effective means of protection such as pressure relief devices or equivalent are to be provided.

4.9.3 Pressure relief valves are to be sized such that any accumulation of pressure from any source will not exceed 121 per cent of the design pressure. For specific fire contingencies where accumulated pressure could exceed 121 per cent, design proposals will be specially considered.

4.9.4 Bursting discs fitted in place of or in series with safety valves are to be rated to burst at a maximum pressure not exceeding the design pressure of the vessel at the operating temperature. Bursting discs are only to be used for pressure vessels located in open areas or if fitted in conjunction with a relief line led to an open area.

4.9.5 Where a bursting disc is fitted downstream of a safety valve, the maximum bursting pressure is also to be compatible with the pressure rating of the discharge system.

4.9.6 In the case of bursting discs fitted in parallel with relief valves to protect a vessel against rapid increase of pressure, the bursting disc is to be rated to burst at a maximum pressure not exceeding 1,3 times the design pressure of the vessel at operating temperature.

4.9.7 Pressure relief devices are to be type tested to establish their discharge capacities at their maximum rated design pressures and temperatures in accordance with an approved Code or Standard.

4.9.8 Where pressure relief devices can be isolated from the pressure vessel whilst in service, there is to be an alternative independent pressure relief device. The system pressure relief valve set pressure and bursting disc rupture pressure should be displayed at the respective operating position.

4.9.9 Any isolating valves used in conjunction with pressure relief devices are to be the full flow type capable of being locked in the full open position. Where isolating valves are arranged downstream and upstream of a relief device they are to be interlocked with each other.

4.9.10 Where pressure relief devices are duplicated on the same vessel or system and fitted with isolating valves, these valves are to be so interlocked as to ensure that before one relief device is isolated the other relief device is fully open and the required discharge capacity is maintained. The interlocking system is to be submitted for approval.

4.9.11 The design of the pressure-relieving system is to take into account the characteristics of the fluid handled and any extreme environmental condition recorded for the geographical zone of operation. The vent and pressure relieving systems are to be self-draining.

4.9.12 The rated discharge capacity of any pressure relief device is to take into account the back pressure in the vent systems. Where hazardous vapours are discharged directly to the atmosphere, the outlets are to be arranged to vent to a safe location.

4.10 Bulk storage vessels

4.10.1 Bulk storage vessels are to be designed in accordance with the general requirements of this Section and with one of the internationally recognised Codes or Standards for fusion welded pressure vessels quoted in Appendix A, A1.2.11, and in accordance with the design requirements given in Section 1, *see also* Ch 7,3.10.

4.10.2 For bulk storage vessels in enclosed areas, testable safety valves are to be used, which can be vented out of the area. Such enclosed areas are to be ventilated so that a pressure build-up will not occur in the event of a break or a leak in the air supply system.

4.10.3 Bulk storage vessels are normally to be supported by suitable skirts in order to distribute the loads into the supporting structure.

4.10.4 Bulk storage vessels which penetrate watertight decks or flats are to be suitably reinforced, *see* Ch 3,2.10.

■ *Section 5* Mechanical equipment

5.1 General

5.1.1 The Rules in this Section are applicable to all types of mechanical equipment associated with the production and process plant, with the exception of pressure vessels which are dealt with in Section 4.

5.1.2 Mechanical equipment is to be designed in accordance with internationally recognised and agreed Codes and Standards and in accordance with the requirements of Section 1.

5.1.3 The list in Appendix A, A1.2 gives reference to some generally recognised Codes and Standards frequently specified for drilling and production equipment. These Codes and Standards may be used for certification, but the additional requirements given in these Rules apply and will take precedence over the Codes and Standards wherever conflict occurs.

5.1.4 Production and process plant equipment is to be suitable for the service intended and for the maximum loads, pressures, temperatures and environmental conditions to which the system may be subjected.

5.2 Plans and data submissions

5.2.1 Design documentation for mechanical equipment is to be submitted in accordance with the equipment categories and certification requirements defined in Section 1.

5.2.2 The submitted information should include the following, as applicable to the equipment categories:

- Design specification, including data of working medium and pressures.
- Minimum/maximum temperatures, corrosion allowance, environmental and external loads.
- Plans, including sufficient detail and dimensions to evaluate the design.
- Strength calculations as applicable.
- Material specifications and welding details.

5.3 Equipment certification

5.3.1 Equipment categories and certification of production and process plant equipment are to be in accordance with the requirements of Section 1.

5.3.2 A general guide to specific equipment categories are given in Table A 2.3 in Appendix A.

5.3.3 Hoisting and pipe handling equipment are to comply with Ch 7,6.

5.3.4 Associated equipment such as oil engines, electric motors, generators, turbines, etc., are to comply with the applicable Sections of the Rules.

5.4 Materials

5.4.1 Materials are to comply with Ch 1,4 and the Rules for Materials, except where modified by this Section.

5.4.2 The selected materials are to be suitable for the purpose intended and must have adequate properties of strength and ductility and materials to be welded shall be of weldable quality.

5.4.3 As a minimum, unless specified by the design specification, Charpy impact tests are required to be carried out at the minimum design temperature (MDT) and exhibit minimum impact energies of 34J for minimum specified yield strengths up to 360 MPa and 40J for higher yield stengths.

5.4.4 For selection of acceptable materials suitable for hydrogen sulphide contaminated products (sour service), reference is to be made to the ISO 15156/NACE Standard in Appendix A, A1.2.21.

5.4.5 Grey iron castings are not to be used for critical components.

5.4.6 Proposals to use spheroidal graphite iron castings for critical components operating below 0°C will be specially considered by LR in each case.

5.4.7 In general, bolts and nuts are to comply with the Standards listed in Appendix A, A1.2.

5.4.8 Bolts and nuts for major structural and mechanical components are to have a tensile strength of not less than 600 N/mm^2.

5.4.9 For general service the specified tensile strength of bolting material should not exceed 1000 N/mm^2.

5.4.10 Where required, materials of high heat resistance are to be used and the ratings are to be verified.

5.5 Design and construction

5.5.1 The design strength of production and process plant equipment is to comply generally with Part 5, as applicable, and with LR agreed Codes and Standards.

5.5.2 All equipment included in this Section is to be suitable for the design environmental conditions for the unit.

5.5.3 Combustion equipment and combustion engines are not normally to be located in a hazardous area, unless the air space is pressurised to make the area non-hazardous in accordance with the following criteria:

- Pressurisation air is to be taken from a safe area.
- An alarm is to be fitted to indicate loss of air pressure.
- An air lock system with self-closing doors is to be fitted.
- The exhaust outlet is to be located in a non-hazardous area, and be fitted with spark arresters, *see* 5.5.4.
- The combustion air inlet is to be located in a non-hazardous area.
- Automatic shut-down is to be arranged to prevent over-speeding in the event of accidental ingestion of flammable gases or vapours.

5.5.4 Efficient spark arresters, of LR approved type, are to be fitted to the exhaust from all combustion equipment, except from exhaust gas turbines. Water cooled spark arresting equipment is to be fitted with means to give a warning in the event of failing cooling water supply.

5.5.5 Exhaust gases are to be discharged so that they will not cause inconvenience to personnel or a dangerous situation during helicopter operations.

5.5.6 The equipment and systems are to be designed, installed, and protected so as to be safe with regard to the risk of fire, explosions, leakages and accidents.

■ *Section 6*
Electrical installations

6.1 General

6.1.1 In general, electrical installations are to comply with the requirements of Pt 6, Ch 2.

6.1.2 Electrical equipment installed in areas where an explosive gas atmosphere may be present is to be in accordance with Pt 7, Ch 2.

■ *Section 7*
Control systems

7.1 General

7.1.1 In general, control engineering systems are to comply with the requirements of Pt 6, Ch 1 and/or the appropriate Codes and Standards defined in Appendix A.

7.1.2 Emergency shut-down systems and other safety and communication systems are to comply with the requirements of Pt 7, Ch 1.

7.1.3 All butt welds are to be subjected to 100 per cent NDE. Examination by radiography is to be to a Standard acceptable to LR, e.g., ISO 17636: *Non-destructive testing of welds – Radiographic testing of fusion welded joints*, with acceptance criteria as detailed in the Construction Code, or BS 4515: *Specification for welding of steel pipelines on land and offshore*, if not specified in the Code. Proposals for examination by ultrasonics are to be submitted for review and acceptance.

■ *Section 8*
Fire, hazardous areas and ventilation

8.1 General

8.1.1 Hazardous areas and ventilation are to comply with Ch 3,3 and Pt 7, Ch 2.

8.1.2 The general requirements for fire safety are to comply with Pt 7, Ch 3.

■ *Section 9*
Riser systems

9.1 General

9.1.1 Production riser systems which comply with the requirements of Chapter 12 will be eligible for the special features class notation **PRS**.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter apply to mobile offshore units with installed dynamic positioning systems and are additional to those applicable in other Parts of these Rules.

1.1.2 A mobile offshore unit provided with a dynamic positioning system in accordance with these Rules will be eligible for an appropriate class notation which will be recorded in the ClassDirect Live Website.

1.1.3 Requirements additional to these Rules may be imposed by the National Administration with whom the unit is registered and/or by the administration within whose territorial jurisdiction it is intended to operate. Where national legislative requirements exist, compliance with such regulations shall also be necessary.

1.1.4 For the purpose of these Rules, dynamic positioning means the provision of a system with automatic and/or manual control capable of maintaining the heading and position of the unit during operation within specified limits and environmental conditions.

1.1.5 For the purpose of these Rules, the area of operation is the specified allowable position deviation from the desired set point, *see* 1.3.2.

1.2 Classification notations

1.2.1 Units complying with the requirements of this Chapter will be eligible for one of the following class notations, as defined in Pt 1, Ch 2:

DP(CM) *See* Section 2.
DP(AM) *See* Section 3.
DP(AA) *See* Section 4.
DP(AAA) *See* Section 5.

1.2.2 The notations given in 1.2.1 may be supplemented with a Performance Capability Rating (**PCR**). This rating indicates the calculated percentage of time that a unit is capable of maintaining heading and position under a standard set of environmental conditions (North Sea), *see* Section 6.

1.2.3 Additional descriptive notes may be entered in the ClassDirect Live Website, indicating the type of position reference system, control system, etc.

1.2.4 Where a **DP** notation is not requested, dynamic positioning systems are to comply with the requirements of Section 2, as far as is practicable.

1.3 Information and plans required to be submitted

1.3.1 The information and plans specified in 1.3.2 to 1.3.7 are to be submitted in triplicate. The Operation Manuals specified in 1.3.8 are to be submitted in a single set.

1.3.2 Details of the limits of the area of operation and heading deviations, together with proposals for redundancy and segregation provided in the machinery, electrical installations and control systems, are to be submitted. These proposals are to take account of the possible loss of performance capability should a component fail, or in the event of fire or flooding, *see also* 1.3.6 and Sections 4 and 5.

1.3.3 Where a common power source is utilised for thrusters, details of the total maximum load required for dynamic positioning are to be submitted.

1.3.4 Plans of the following, together with particulars of ratings in accordance with the relevant Parts of the Rules, are to be submitted for:

(a) Prime movers, gearing, shafting, propellers and thrust units.
(b) Machinery piping systems.
(c) Electrical installations.
(d) Pressure vessels for use with dynamic positioning system.

1.3.5 Plans of control, alarm and safety systems, including the following, are to be submitted:

(a) Functional block diagrams of the control system(s).
(b) Functional block diagrams of the position reference systems and the environmental sensors.
(c) Details of the electrical supply to the control system(s), the position reference system(s) and the environmental sensors.
(d) Details of the monitoring functions of the controllers, sensors and reference system, together with a description of the monitoring functions.
(e) List of equipment with identification of the manufacturer, type and model.
(f) Details of the control stations, e.g., control panels and consoles, including the location of the control stations.
(g) Test schedules (for both works testing and sea trials) that are to include the methods of testing and the test facilities provided.

1.3.6 For assignment of a **DP(AA)** or **DP(AAA)** notation, a Failure Mode and Effect Analysis (FMEA) is to be submitted, demonstrating that adequate segregation and redundancy of the machinery, the electrical installation and the control systems have been achieved in order to maintain position in the event of equipment failure, *see* Section 4, or fire or flooding, *see* Section 5. The FMEA is to take a formal and structured approach and is to be performed in accordance with an acceptable and relevant national or international standard, e.g., IEC 60812.

1.3.7 Where the **DP** notation is to be supplemented with a Performance Capability Rating (PCR), *see* 1.2.2, the following information is to be submitted for assignment of a PCR:

(a) Lines plan.
(b) General arrangement.
(c) Details of thruster arrangement.
(d) Thruster powers and thrusts.

1.3.8 Operation Manuals, including details of the dynamic positioning system operation, installation of equipment, maintenance and fault finding procedures, together with a section on the procedure to be adopted in an emergency, are to be submitted. A copy of the manual is to be placed and retained on board the unit.

■ *Section 2* Class notation DP(CM)

2.1 Requirements

2.1.1 The requirements for class notation **DP(CM)** are given in Pt 7, Ch 4,2 of the Rules for Ships, which are to be complied with where applicable.

■ *Section 3* Class notation DP(AM)

3.1 Requirements

3.1.1 The requirements for class notation **DP(AM)** are given in Pt 7, Ch 4,3 of the Rules for Ships, which are to be complied with where applicable.

3.1.2 Additional requirements with respect to unit types as indicated in this Section should also be complied with as applicable.

3.1.3 A manually initiated emergency alarm, clearly distinguishable from all other alarms associated with the dynamic positioning system, is to be provided at the dynamic positioning control station to warn all relevant personnel in the event of a total loss of dynamic positioning capability. In this respect, consideration should be given to additional alarms being provided at locations such as the Master's accommodation and operational control stations.

■ *Section 4* Class notation DP(AA)

4.1 Requirements

4.1.1 The requirements for class notation **DP(AA)** are given in Pt 7, Ch 4,4 of the Rules for Ships, which are to be complied with where applicable.

■ *Section 5* Class notation DP(AAA)

5.1 Requirements

5.1.1 The requirements for class notation **DP(AAA)** are given in Pt 7, Ch 4,5 of the Rules for Ships, which are to be complied with where applicable.

■ *Section 6* Performance Capability Rating (PCR)

6.1 Requirements

6.1.1 The requirements for Performance Capability Rating (PCR) are given in Pt 7, Ch 4,6 of the Rules for Ships, which are to be complied with where applicable.

■ *Section 7* Testing

7.1 Requirements

7.1.1 The requirements for testing are given in Pt 7, Ch 4,7 of the Rules for Ships, which are to be complied with where applicable.

Section

■ *Section 1* General

1.1 Application

1.1.1 Mobile offshore units with positional mooring systems complying with the requirements of this Chapter will be eligible for the assignment of a special features notation.

1.1.2 The mooring system will be considered for classification on the basis of operating constraints and procedures specified by the Owner and recorded in the Operations Manual.

1.1.3 Requirements additional to these Rules may be imposed by the National Authority with whom the unit is registered and/or by the Administration of the coastal state(s) with territorial jurisdiction over the waters in which it is intended to operate.

1.2 Class notations

1.2.1 The Regulations for classification and the assignment of class notations are given in Pt 1, Ch 2, to which reference should be made.

1.2.2 Units provided with a positional mooring system which complies with the requirements of this Chapter will be eligible for the assignment of a special features class notation as follows:

PM (Positional mooring system), or

PMC (Positional mooring system for mooring in close proximity to other vessels or installations. This notation will apply in particular to any unit operating adjacent to a fixed installation, e.g., crane unit, accommodation unit, support unit, etc.).

1.2.3 Units fitted with a thruster-assisted positional mooring system which complies with the requirements of this Chapter will be eligible for the assignment of one of the following supplementary special features class notations:

TA(1)
TA(2)
TA(3)

1.2.4 The numeral in parenthesis after the thruster-assist notation **TA** in 1.2.3 defines the thruster allowance which may be permitted in the design of the positional mooring system, and is determined by the capacity/redundancy of the thrust/machinery installation, *see* Sections 4, 14 and 15.

1.2.5 For units with positional mooring systems, a typical example of character of classification and class notations is:

+OU 100A1 Mobile Drilling Unit, **DRILL**, **PM TA(3)**.

1.3 Definitions

1.3.1 The definitions given in this Section are for Rule application only and will not necessarily be valid in any other context, *see also* Pt 1, Ch 2,2.

1.3.2 **Positional mooring**. Station-keeping by means of multi-leg mooring system with or without thruster-assist. The positional mooring system will consist of the following components, as relevant:

(a) Anchor points:
- Drag embedment anchors.
- Anchor piles.
- Suction anchor piles.
- Gravity anchors.
- Plate anchors.

(b) Anchor lines.

(c) Anchor line fittings:
- Shackles.
- Connecting links/plates.
- Wire rope terminations.
- Clump weights.
- Quick release devices, etc.

(d) Fairleads/bending shoes.

(e) Chain or wire rope stoppers.

(f) Winches or windlasses.

Where applicable, the structural or mechanical connection of these items to the unit is also considered to be part of the positional mooring system.

1.3.3 **Thruster-assist**. The use of thrusters, inclusive of their associated equipment, to supplement the unit's positional mooring system.

1.3.4 **Catenary mooring**. A mooring system which derives its compliancy mainly from the catenary action of the anchor lines. Some additional resilience is provided by the characteristic axial elasticity of the anchor lines.

1.3.5 **Taut-leg mooring**. A mooring system based on light-weight anchor lines pre-tensioned to a taut configuration with no significant catenary shape at any unit offset, and applying vertical and horizontal loads at the anchor points. With this type of system, compliancy is derived from the inherent axial elastic stretch properties of the anchor line.

1.3.6 **Spread mooring**. A multi-line mooring system designed to maintain an offshore unit on an approximately fixed heading.

1.4 Plans and data submission

1.4.1 The positional mooring system will be subject to review and approval. The following information and plans are to be submitted in triplicate, to cover the design review and class approval of the positional mooring system:

(a) Plans of the positional mooring system and associated equipment are to be submitted, including the following, as applicable:
- General arrangement of floating unit.
- Mooring layout.
- Anchor lines and fittings.
- Anchor points.
- Fairleads/bending shoes.
- Cable stoppers.
- Winches, windlasses or tensioners.

(b) For thruster-assisted positional mooring systems, plans of the following, together with particulars of ratings, in accordance with the relevant Parts of these Rules, are to be submitted for the following:
- Prime movers, gearing, shafting, propellers and thrust units, *see also* Part 5.
- Machinery piping systems.
- Electrical installations.

(c) In addition, details of proposals for the redundancy provided in machinery, electrical installations, and control systems are to be submitted. These proposals are to take account of the possible loss of performance capability should a component fail. Where a common power source is utilised for thrusters, details of the total maximum load required for thruster-assist are to be submitted.

(d) Plans of control, alarm and safety systems, including the following, are to be submitted:
- Functional block diagrams of the control system(s).
- Functional block diagrams of the position reference systems and environmental sensors.
- Details of electrical supply to the control system(s), the position reference system(s) and the environmental sensors.
- Details of the monitoring functions of the controllers, sensors and reference system together with a description of the monitoring functions.
- List of equipment with identification of the manufacturer, type and model.
- Details of the overall alarm system linking the centralised control station, subsidiary control stations, relevant machinery spaces and operating areas.
- Details of control stations, e.g., control panels and consoles, including the location of the control stations.
- Factory and customer acceptance test schedules which are to include the methods of testing and the test facilities provided.

1.4.2 Single copies of the following supporting plans, data, calculations or documents are to be submitted:

(a) General:
- Mooring design premise.
- Moored unit details (dimensions and main particulars).

(b) Specifications:
- Materials.
- Equipment and fittings.
- Model testing.

(c) Data reports:
- Environmental criteria.

(d) Design reports and calculations:
- Hydrodynamic/motion analysis.
- Mooring analysis.
- Model test results.
- Design load report.
- Anchor line components: strength and fatigue.
- Anchor point: strength and fatigue.
- Fatigue.
- Equipment/ancillaries including the associated equipment, stoppers and fairleads: strength and fatigue.
- Corrosion protection and/or corrosion allowance.

(e) Other information:
- In-service inspection programme.
- Anchor point holding capacity.

1.4.3 An Operations Manual, as required by Ch 1,3, is to be submitted and the Manual is to contain all necessary information and instructions regarding positional mooring and, where relevant, thruster-assisted positional mooring. It would normally also contain descriptions of the following:
- Mooring systems.
- Laying the mooring system.
- Anchor pre-loading.
- Pre-tensioning anchor lines.
- Tension adjustment.
- Winch/windlass performance.
- Winch/windlass operation.
- Procedure in event of failure or emergency.
- Procedure for operating thrusters.
- Fault-finding procedures for thruster-assist system.
- Maintenance procedures.

Section 2
Survey

2.1 General requirements

2.1.1 Positional moorings, with or without thruster-assist, are to be inspected and tested during manufacture/ construction, and under working conditions on completion of the installation.

2.1.2 The scope of inspection and/or testing to be carried out at the manufacturer's works is to be agreed with LR before the work is commenced.

2.1.3 The general requirements for Periodical Surveys contained in Pt 1, Ch 2 of the Rules are to be complied with.

2.1.4 For guidance on the inspection of positional mooring systems, *see* Appendix B.

Section 3
Environmental conditions

3.1 General

3.1.1 The Owner/Operator or designer is to specify the environmental criteria for which the unit is to be considered. The extreme environmental conditions applicable to the operating areas are to be specified, together with all operating environmental limits. Detailed specialist environmental reports are to be submitted, with sufficient supporting information to demonstrate the validity of the limiting criteria, *see* 3.3.

3.1.2 A comprehensive set of operating and extreme environmental limiting conditions is to be submitted. This is to cover the following cases, as applicable, and any other conditions relevant to the system under consideration:

- Extreme environmental conditions.
- Limiting environmental conditions in which the unit may remain moored.
- Limiting environmental conditions in which the unit's main operating functions may be carried out (e.g., drilling, gangway connection, etc.).
- Limiting environmental conditions in which the unit may (re)connect.

3.2 Environmental factors

3.2.1 The following environmental factors are to be considered in the design of the positional mooring system:

- Water depth range.
- Wind including gust spectral characteristics.
- Significant wave height.
- Wave period.
- Wave spectral characteristics.
- Current.
- Relative angles between wind, wave and current (for weathervaning units).
- Marine growth.
- Air and sea temperatures.

3.2.2 In certain locations, the following factors may need to be considered in the design of the positional mooring system:

- Ice.
- Seismic events, such as earthquakes.

3.3 Metocean data

3.3.1 As part of the environmental data, the following metocean data will normally be required to be submitted:

- 50, 10 and 1-year return period values for wind-speed, significant wave height and current.
- Directional data for extreme values of wind, waves and current.
- Wave height/period joint frequency distribution (wave scatter diagram).
- Wave spectral parameters.
- Wind/wave/current angular separation data.
- Current speed and/or directional variation over the water depth.
- Long-term wave statistics by direction.

3.4 Environmental parameters

3.4.1 **Water depth**. Minimum and maximum still water levels are to be determined, taking account of the tidal range, sea bed subsidence, wind and pressure surge effects.

3.4.2 **Wind**. The 1-hour wind speed, plus wind gust spectrum, will normally require to be applied in design. The following wind gust spectra formulations can be adopted for the time varying component:

- API RP 2A, *Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platform*.
- Other published spectra formulations may be accepted (Harris, Slettringen), *see* Appendix A, A1.2.17.

Estimating wind forces and moments for design input into analysis or model basin wind fields should preferably be done on the basis of wind tunnel tests using an accurate project-specific model.

3.4.3 **Waves**:

(a) To ensure that the most critical combinations of low frequency and wave frequency response are determined, a broad range of significant wave heights and peak periods will require to be investigated, preferably based on the use of a 50-year wave contour.

(b) For this approach, a wave contour of significant wave height and peak period combinations will require to be developed, using appropriate extrapolation techniques, to extend shorter term wave height and period joint frequency distribution data. Each point on the wave contour will represent a combination of H_s and T_p having a 50-year recurrence interval. Appropriate methods of developing the wave contour are to be used, *see* Appendix A,A1.2.18.

(c) The method of determining the wave contour is to be documented and included with the design submission package. Where adequate wave height/period joint distribution data is not available to enable such a contour to be produced, a conservative choice of wave period range will require to be applied in the design.

(d) As the wave spectrum is a combination of wind-driven waves and swell, consideration will need to be given for certain locations, to the joint occurrence and angular separation between these two components.

3.4.4 **Current**. Design current velocities are to be established, taking account of all relevant components including the following:

- Tidal currents.
- Circulation currents.
- Wind-driven current.
- Storm surge generated current.

3.4.5 **Marine growth**. Account is to be taken in the design of build-up of marine growth on the anchor lines, riser system and/or the hull, and the resulting increase in load and damping. The thickness of marine growth taken into account is to be stated in the Operations Manual and is not to be exceeded in service.

3.4.6 **Air and sea temperature**. The minimum and maximum air and sea temperatures are to be specified in accordance with Chapter 1.

3.4.7 **Sea ice and icebergs**. The design philosophy of units intended to be moored in regions subject to sea ice or icebergs will require to be defined, including any quick-release mooring system arrangements.

3.4.8 **Seismic**. The requirements for units intended to be moored in regions subject to seismic events, such as earthquakes or tsunamis, will be subject to special consideration.

■ *Section 4* Design aspects

4.1 Design cases

4.1.1 The positional mooring system, with or without thruster-assist, is to be designed for the following:

(a) **Intact case**:
- This case assumes all anchor lines to be effective. Thruster-assist from an approved system can be included, *see* 4.2.

(b) **Damaged case**:
- This case involves the failure of a single component, i.e. failure of an anchor line or anchor point, or failure of a component in the case of thruster-assist.
- Note that a single failure in the thruster system could lead to stoppage of several, or all, of the thrusters.

(c) **Transient case**:
- The transient case will not normally require to be investigated.

4.2 Thruster-assist systems

4.2.1 Thrusters can be used to reduce the mean load on the mooring system, provide damping of low frequency surge motion, and/or control the heading of the unit, in order to limit the overall excursions. Thruster intervention allowances for supplementary thruster-assist notations is given in Table 10.4.1.

Table 10.4.1 Thruster allowance

Case	Thruster allowance		
	TA(1)	**TA(2)**	**TA(3)**
Operating (Intact)	None	70% of all thrusters	All thrusters
Survival (Intact)	70% of all thrusters	All thrusters	All thrusters
Operating (Single line failure)	None	70% of all thrusters	All thrusters
Survival (Single line failure)	70% of all thrusters	All thrusters	All thrusters

NOTES
1. The conditions for assignment of supplementary notations **TA(1)**, **TA(2)** and **TA(3)** are defined in Section 14.
2. Net thrust values can be applied in the calculations, to the extent indicated in the Table. The basis for deductions due to thruster-hull, thruster-current and thruster-thruster interference is to be documented and included in the design submission.
3. *See* 4.1.1 for the Rule basis of failure, including thruster system failure, for damaged case.

4.2.2 Units which utilise thruster assistance as an aid to position keeping or as a means of reducing anchor line tensions, and which have a system approved by LR, may be assigned a special features notation as defined in 1.2.

4.2.3 The requirements of Sections 14 and 15 are to be complied with and for the majority of offshore units with positional mooring systems which utilise thruster assistance the class notation **TA(3)** will be applicable. Thruster-assist notations **TA(1)** and **TA(2)** will only be considered for applications of low criticality.

4.3 Design environmental conditions

4.3.1 Unless agreed otherwise with LR, the following design environmental combinations are to be considered:

(a) 50-year waves + 50-year wind + 10-year current.

(b) 50-year waves + 10-year wind + 50-year current.

Joint probabilities of the various environmental actions may be taken into account if such information is available and can be adequately documented.

4.3.2 For 50-year waves, a range of different wave height/period combinations, each of which has a joint recurrence period of 50 years, will require to be considered, *see* 3.4.3.

4.3.3 Directional combinations are given in 4.4.

4.4 Directional combinations

4.4.1 For weathervaning units, sufficient combinations of directions of wind and current relative to wave direction are to be investigated to ensure the critical cases are found, swell is to be superimposed from the worst case direction, *see* 3.4.3(d). The following combinations are envisaged as a minimum for design (unless joint directional probabilities of the various environmental actions are available and can be adequately documented):

(a) Wave, wind and current collinear.
(b) Wind and current at 30° to waves.
(c) Wind at 30° to waves, and current at 90° to waves.

NOTE
For case (c) above, only combination (a) given in 4.3.1 has to be considered (i.e., the 50-year current case is not applicable).

4.5 Environmental directions relative to unit and mooring system

4.5.1 For spread-moored units, at least head, quartering, beam relative to the unit and down-line directions are to be considered in mooring analysis. Dependent on response analysis and wind, wave and current force/moment calculations, other directions may require to be considered, *see also* 4.4.1.

4.5.2 For weathervaning units, the following cases must be considered as a minimum requirement:

- Wave direction along mooring line.
- Wave direction between mooring lines.

4.5.3 Where the mooring lines are grouped, additional wave directions will require to be considered at intermediate headings between the directions given above.

4.5.4 For a positional mooring system without thruster-assist, two conditions will normally need to be analysed:

- loss of highest loaded line, leading to highest excursions; and
- loss of second highest loaded line, leading to highest line tensions.

4.6 Other design aspects

4.6.1 Anchor lines are to have adequate clearance from sub-sea equipment such as templates, flowlines, etc.

4.6.2 The design of the mooring system is to take account of the offset limits required by the drill string or riser system, and the avoidance of contact between risers and anchor lines.

4.6.3 Where an operational activity is intended to be continued during periods where an anchor line is disconnected for inspection, etc., specific environmental limitations are to be established to ensure that safety factors are maintained even with one line out of action. A similar procedure applies when machinery and equipment cannot remain fully functional during maintenance and inspection.

4.6.4 In cases where the mooring system is intended to be actively controlled by adjustment of line lengths and tensions, satisfactory evidence must be submitted to show that the adjustment procedure is practical, taking account of winch control and prevailing environmental conditions.

4.6.5 Where units are moored in areas where high velocity currents occur, dynamic excitation due to vortex shedding is to be considered.

4.6.6 Positional mooring systems for units intended to remain on station for more than five years should comply with LR's *Rules and Regulations for the Classification of a Floating Offshore Installation at a Fixed Location*.

■ *Section 5*
Design analysis

5.1 General

5.1.1 A comprehensive analysis will be required in all cases and model tests are normally to be performed for ship shape units or unique designs. Validation will be required for each part of the analysis process, by correlation with model tests or other proven method.

5.2 Model testing

5.2.1 The model test programme and test facilities are to be to LR's satisfaction.

5.2.2 The model is to be of an adequate scale and is to represent fully the moored unit. Account is to be taken of the different draughts, deck structures and large equipment appendages such as anchor racks or thrusters. In case of (ultra) deep water moorings, the scale and representation of the moorings will be subject to special consideration.

5.2.3 The tests are to be of sufficient duration to establish the low frequency behaviour, and most probable maxima with sufficient reliability.

5.2.4 The tests are to include means of establishing the effects of green water and/or slamming, through video recordings of the model testing, and by measurement of the following:

- Relative motions.
- Forces on local panels mounted at various locations such as bow area and accommodation.

5.2.5 It is recommended that an initial analysis be performed prior to the start of the model test programme, in order to understand and clarify the conceptual design, and to help focus the model testing on the most important design parameters.

5.3 Analysis aspects

5.3.1 The analysis is to take account of the following:

- The effect of current on wave drift force.
- The effect of water depth on current forces, first order responses and wave drift.

5.3.2 For response analysis, anchor line properties are to be based on the total line diameter including corrosion allowance, *see* Table 10.8.1.

5.3.3 Weight and elasticity properties of anchor lines are to be obtained from chain or rope manufacturers. This information is to be documented and included in the submission.

5.4 Analysis

5.4.1 The following analyses, which may be combined, are to be carried out and submitted to LR:

- Hydrodynamic analysis of the floating unit.
- Motions analysis of the moored unit.
- Mooring analysis.

5.4.2 The following data has to be derived from the analyses:

- Steady force offsets, and tensions, from wind, current and wave drift.
- Wave frequency motions/accelerations.
- Low frequency offsets and tensions from second order wave drift forces, and wind gust effects.

5.4.3 Time domain or frequency domain analysis methods can be applied. The basis for linearisation of the frequency domain analysis is to be documented.

5.4.4 For low frequency response analysis, the non-linear stiffness characteristics are to be satisfactorily represented. The amplitude of low frequency motion will be highly dependent on system damping from the following:

- Current.
- Wave drift.
- Viscous effects on the hull.
- Anchor lines and risers.
- Wind effects.

Thruster damping may also be applicable in relevant cases and the basis for the damping terms used in the analysis is to be documented and submitted.

5.4.5 Tensions due to low frequency and wave frequency excitation can be computed separately. The effect of line dynamics is to be accounted for in wave frequency analysis. Low frequency tension can be based on quasi-static catenary response. Wave frequency dynamic line tension is to be computed at alternative low frequency offset positions, *see* 5.5.3.

5.5 Combination of low and high frequency components

5.5.1 Maximum design values for offset and tension are preferably to be derived from combined wave frequency and low frequency response analyses. The time domain simulations are to be of sufficient length to establish reasonable confidence levels in the predictions of maximum response.

5.5.2 The most probable maximum values for tension and offset can be determined from the distribution of peak values. The statistical basis (Weibull, etc.) being applied to derive the probability distribution is to be documented and submitted.

5.5.3 Tensions and offset values can be combined as follows, when low frequency and wave frequency analyses are conducted separately:

(a) Offset:

$$X_{MAX} = X_{MEAN} + X_{LF\ sig} + X_{WF\ max}$$

or

$$X_{MAX} = X_{MEAN} + X_{LF\ max} + X_{WF\ sig}$$

whichever is the greater

where

X_{MAX} = maximum vessel offset
X_{MEAN} = mean vessel offset
$X_{LF\ sig}$ = significant low frequency offset
$X_{LF\ max}$ = maximum low frequency offset
$X_{WF\ sig}$ = significant wave frequency offset
$X_{WF\ max}$ = maximum wave frequency offset.

(b) Tension:

$$T_{MAX} = T_{MEAN} + T_{LF\ sig} + T_{WF\ max}$$

or

$$T_{MAX} = T_{MEAN} + T_{LF\ max} + T_{WF\ sig}$$

whichever is the greater

where

T_{MAX} = maximum tension
T_{MEAN} = tension at mean vessel offset
$T_{LF\ sig}$ = significant low frequency tension
$T_{LF\ max}$ = maximum low frequency tension
$T_{WF\ sig}$ = significant wave frequency tension computed at maximum low frequency offset position, $X_{LF\ max}$
$T_{WF\ max}$ = maximum wave frequency tension computed at significant low frequency offset position, $X_{LF\ sig}$.

5.5.4 Estimates of maximum design values can be based on the following:

(a) Low frequency:

$$X_{LF\ sig} = 2\sigma_{x\,LF}$$

$$X_{LF\ max} = \sigma_{x\,LF}\sqrt{2(\ln N_{LF})}$$

$$T_{LF\ sig} = 2\sigma_{T\,LF}$$

$$T_{LF\ max} = \sigma_{T\,LF}\sqrt{2(\ln N_{LF})}$$

where

$X_{LF\ sig}$ = significant low frequency offset
$X_{LF\ max}$ = maximum low frequency offset
$T_{LF\ sig}$ = significant low frequency tension
$T_{LF\ max}$ = maximum low frequency tension
σ_{xLF} = standard deviation of low frequency offset
σ_{TLF} = standard deviation of low frequency tension

N_{LF} = number of low frequency oscillations during short-term storm state (not less than 3 hour storm)

ln = $\log_e$.

e = base of natural logarithms, 2,7183.

(b) Wave frequency:

$X_{WF\ sig} = 2\sigma_{x\ WF}$

$X_{WF\ max} = \sigma_{x\ WF} \sqrt{2(\ln N_{WF})}$

$T_{WF\ sig} = 2\sigma_{T\ WF}$

$T_{WF\ max} = \sigma_{T\ WF} \sqrt{2(\ln N_{WF})}$

where

$X_{WF\ sig}$ = significant wave frequency offset

$X_{WF\ max}$ = maximum wave frequency offset

$T_{WF\ sig}$ = significant wave frequency tension

$T_{WF\ max}$ = maximum wave frequency tension

$\sigma_{x\ WF}$ = standard deviation of wave frequency offset

$\sigma_{T\ WF}$ = standard deviation of wave frequency tension

N_{WF} = number of wave frequency oscillations during short-term storm state (not less than 3 hour storm)

ln = $\log_e$

e = base of natural logarithms, 2,7183.

■ *Section 6* Anchor lines

6.1 General

6.1.1 Anchor line length is to be sufficient to avoid uplift forces occurring at the anchor point for damaged condition loads, unless the anchor point is specially designed to accept a vertical component of loading.

6.1.2 An anchor line tension measurement system or device will require to be provided.

6.1.3 Steel wire rope and chain requirements are defined in Sections 7 (Wire ropes) and 8 (Chains) respectively.

6.1.4 The break strength of the anchor line is not to be greater than the load bearing capacity of the connecting structure, *see* Pt 4, Ch 6,1.

6.2 Factors of safety – Strength

6.2.1 **PM** notation (including **PM TA(1)**, **PM TA(2)** and **PM TA(3)**). Minimum factors of safety applicable to steel wire rope and chain anchor lines of moored floating units are given in Table 10.6.1.

Table 10.6.1 Factors of safety for PM notation

Design case	Description	Factors of safety for **PM** notation, *see* Note 1	
		Quasi-static analysis	Dynamic analysis
1	Operating (Intact)	2,7	2,3
2	Survival (Intact)	1,8	1,5
3	Operating (Single line failure)	1,8	1,5
4	Survival (Single line failure)	1,25	1,1

NOTES
1. The factors of safety given in this Table apply to units positioned at least 300 m from another installation.
2. The unit is to be positioned to avoid contact with another installation in any of the design cases.

6.2.2 **PMC** notation (including **PMC TA(1)**, **PMC TA(2)** and **PMC TA(3)**). Minimum factors of safety applicable to steel wire rope and chain anchor lines for mooring system analysed quasi-statically and dynamically are given in Tables 10.6.2 and 10.6.3 respectively.

Table 10.6.2 Factors of safety for PMC notation – Quasi-static analysis

Design case	Description	Factors of safety for PMC notation Quasi-static analysis, *see* Note			
		Unit moored 50 m or less from other structures		Unit moored within 50 to 300 m from other structures	
		Critical line	Non-critical line	Critical line	Non-critical line
1	Operating (Intact)	3,0	2,7	3,0	2,7
2	Survival (Intact)	—	—	2,0	1,8
3	Operating (Single line failure)	2,0	1,8	2,0	1,8
4	Survival (Single line failure)	—	—	1,5	1,33

NOTES
1. *See also* 5.4.
2. The unit is to be positioned to avoid contact with another installation in any of the design cases.

Table 10.6.3 Factors of safety for PMC notation – Dynamic analysis

Design case	Description	Factors of safety for PMC notation Dynamic analysis, *see* Note			
		Unit moored 50 m or less from other structures		Unit moored within 50 to 300 m from other structures	
		Critical line	Non-critical line	Critical line	Non-critical line
1	Operating (Intact)	2,5	2,3	2,5	2,3
2	Survival (Intact)	—	—	1,65	1,5
3	Operating (Single line failure)	1,65	1,5	1,65	1,5
4	Survival (Single line failure)	—	—	1,35	1,2

NOTES
1. *See also* 5.4.
2. The unit is to be positioned to avoid contact with another installation in any of the design cases.

6.3 Fatigue life

6.3.1 The fatigue lives of the anchor lines, etc., do not normally need to be calculated unless the unit is to remain moored at one location for more than five years, *see also* 4.6.6.

6.3.2 Where fatigue line lives are required to be calculated, for units which are to operate at one location for a prolonged period, the fatigue life of the main components in the positional mooring system is to be verified and calculations are to be submitted.

6.3.3 Where applicable, tension bending fatigue calculations at fairlead/stopper will need to be considered (e.g. for taut-leg mooring systems).

6.3.4 Fatigue life calculations for anchor lines can be carried out in accordance with a recognised Code, e.g., API 2SK: *Recommended Practice for Design and Analysis of Stationkeeping Systems for Floating Structures*.

6.3.5 Consideration will be given to the use of alternative methods; detailed proposals are to be submitted and agreed with LR.

6.3.6 The minimum factors of safety on the calculated fatigue lives for components of the mooring system are to comply with Table 5.5.2 in Pt 4, Ch 5.

■ *Section 7* Wire ropes

7.1 General

7.1.1 Steel wire ropes for anchor lines are in general to comply with this Section.

7.1.2 Wire ropes and associated fittings are to be of an approved design.

7.2 Rope construction

7.2.1 In selecting a rope construction the following considerations apply:
- Required service life.
- Position in catenary.
- Axial stiffness properties of rope.
- Bending over sheaves, etc.
- Characteristic torsional properties of rope construction.

7.2.2 Various rope constructions can be accepted for long-term mooring applications. These include:
- Spiral strand.
- Locked coil.
- Six-strand.

Other constructions can be considered.

7.3 Design verification

7.3.1 The design of wire rope and associated fittings is to be verified. The following information will be required for appraisal and information:
- Plans of rope, socket and other fittings.
- Materials.
- Design specification.
- Purchaser's specification.
- Codes and Standards applied.
- Calculations for the strength and fatigue of rope, socket, fittings, and their corrosion protection,
- Torsional stiffness data.

7.3.2 Data from prototype rope tests is to be made available as required.

7.3.3 Fatigue life calculations for steel wire ropes can be carried out in accordance with a recommended Code, e.g., API RP 2SK: *Recommended Practice for Design and Analysis of Stationkeeping Systems for Floating Structures*. Rope bending fatigue effects are to be included where relevant.

7.3.4 The minimum factors of safety on the calculated fatigue lives of wire rope and fittings are to comply with Table 5.5.2 in Pt 4, Ch 5.

7.3.5 The rope termination including the socket is to be designed to withstand a load of not less than the minimum breaking strength of the attached wire rope.

7.4 Materials

7.4.1 Steel wire used for rope manufacture is to be manufactured in accordance with a recognised National Standard:

(a) The steel is to be of homogeneous quality, consistent strength, and free from visual defects likely to impair the performance of the rope.

(b) The minimum tensile strength of the wire is to be the tensile strength ordered. The maximum tensile strength is not to exceed the specified minimum strength by more than 230 N/mm^2. The tensile strength should normally be within the range 1420 to 1770 N/mm^2.

7.4.2 The material used in the manufacture of sockets is to comply with the following requirements:

(a) Cast sockets:
- Castings are to be manufactured and tested generally in accordance with Chapter 4 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).
- As a supplement to Chapter 4 of the Rules for Materials, impact tests are to be carried out at a test temperature of minus 20°C, to satisfy a minimum average energy requirement of 40 J, with no more than one individual result from each three test specimens being less than 70 per cent of the required minimum average. Increased material toughness may be required in specific cases.
- Alternative casting standards to Chapter 4 of the Rules for Materials complying with recognised National or proprietary specifications may be accepted, *see also* Ch 4,1.1.3 of the Rules for Materials.

(b) Fabricated sockets:
- Plate material to be Grade D or DH quality in accordance with Chapter 3 of the Rules for Materials. Increased material toughness may be required in some cases.
- Plate with through-thickness properties will generally be required, in accordance with Ch 3,8 of the Rules for Materials.

(c) Socket pins:
- Socket pins may be cast or forged. Where cast, material requirements are to comply with (a) above. Forged socket pins are to be manufactured in accordance with Chapter 5 of the Rules for Materials.
- As a supplement to Chapter 5 of the Rules for Materials, impact tests are to be carried out at a test temperature of minus 20°C, to satisfy a minimum average energy requirement of 40 J, with no more than one individual result from each three test specimens being less than 70 per cent of the required minimum average. Increased material toughness may be required in specific cases.
- Alternative standards to Chapter 5 of the Rules for Materials complying with recognised National or proprietary specifications may be accepted, *see also* Ch 5,1.1.3 of the Rules for Materials.

7.5 Corrosion protection

7.5.1 Wire ropes are to be protected against corrosion. The corrosion protection will normally consist of galvanising or other sacrificial coating of individual wires. Filler wires of zinc or other suitable sacrificial material can be incorporated in the outer layers of the rope, as an addition to, but not in place of, galvanising of individual wires.

7.5.2 Galvanising to meet the following minimum standards:

(a) Zinc:
- BS EN 1179.

(b) Zinc weight:
- ASTM A 603 Table 5, Class A (spiral strand and locked coil).
- ISO 2232, Quality B (six-strand ropes).

(c) Alternative recognised Standards providing acceptable equivalence will be considered.

7.5.3 Sockets are to be protected against corrosion by sacrificial anodes or acceptable equivalent.

7.5.4 Suitable arrangements are to be made to insulate the corrosion protected rope/socket assembly from adjacent non-protected elements in the system.

7.5.5 Polyethylene sheathing can also be used on appropriate rope constructions, as an addition to, but not normally as an alternative to, galvanising:

(a) Where sheathing is intended to be fitted, the specification is to be submitted. ASTM D 1248 is an acceptable specification for medium or high density polyethylene sheathing.

(b) A continuous strip of contrasting colour is to be incorporated into the sheathing to aid monitoring for twist.

7.6 Manufacture and testing

7.6.1 Steel wire ropes are to be manufactured in accordance with the design standards and procedures and at a works approved by LR. Ropes and fittings will be subject to LR survey during manufacture and testing.

7.6.2 A certified ISO 9001/9002 Quality System is to be in place and a quality plan is to be produced and agreed with LR Surveyors.

7.6.3 Where sheathing is specified, it is to be carried out in accordance with the Quality Plan.

7.6.4 Cast sockets are to be manufactured and tested in accordance with the requirements of 7.4.2(a).

7.6.5 The following minimum requirements for the non-destructive testing of cast sockets are applicable:

(a) **Ultrasonics**: All areas of all sockets and pins.
(b) **Radiography**: Critical areas of first, last, and one intermediate socket selected by LR Surveyor to be examined. Critical areas to be identified on design drawings, and these to be included in the design submission for verification.
(c) **Magnetic Particle Inspection (MPI)**: 100 per cent of all sockets and pins.
(d) **Visual**: 100 per cent of all sockets and pins.

7.6.6 The material of plate fabricated sockets is to comply with 7.4.2(b) and welding and NDE to be in accordance with Pt 4, Ch 8. Post-weld heat treatment to be carried out for thicknesses exceeding 65 mm.

7.6.7 Tests are to be carried out on individual wires for the following:

- Tensile strength and elongation.
- Torsion.
- Reverse bend.
- Zinc coating; mass, uniformity and adhesion.

Tests are to be carried out in accordance with recognised National Standards such as ISO 2232 and ASTM A603, as appropriate.

7.6.8 Rope production samples are to be tested for the following:

- Modulus.
- Minimum breaking strength.

7.6.9 The tests required by 7.6.8 are to be as follows:

(a) The modulus test is to be carried out on one finished rope sample taken from the first production length. Production sockets need not be fitted for this particular test. Load/extension characteristics and permanent stretch are to be determined and documented. Acceptance criteria for permanent stretch are to be as follows:
  - Maximum of 0,4 per cent for spiral strand and locked coil ropes.
  - Maximum of 0,8 per cent for six-strand ropes.

  The modulus of elasticity is to be calculated and documented. The basis for the calculated value (cross-sectional metallic area, or area of circle enclosing the rope) is to be clearly stated.
(b) Breaking load test is to be carried out on one sample taken from each manufactured length.
  - Where the rope design, the machine, and the machine settings are identical, consideration can be given to a reduction in the number of tests. As a minimum, breaking load tests are to be carried out on a sample taken from each of the first manufactured length, and one other length, selected by LR Surveyors.
  - Tests are to be carried out in accordance with a recognised National Standard such as DIN 51201.
  - One of the rope samples is to be fitted at one end with a socket taken from the project production batch, and socketed in accordance with approved procedures. Where more than one socket design type is involved, a further assembly is to be tested for each different type of socket.
  - The rope sample and the production socket are to withstand the specified minimum breaking load. The socket pin is to be able to be removed after the test, and replaced, without the application of undue force.
  - NDE to be carried out on the socket following test (100 per cent visual and 100 per cent MPI).

7.7 Identification

7.7.1 Each wire rope assembly is to be marked at each end with the letters LR and the Certificate Number.

7.8 Certification

7.8.1 A certificate is to be issued for each rope assembly by LR. The following is to be included in the Certificate:

- Purchaser's name and order number.
- Description of order, including wire rope diameter and construction.
- Tested minimum breaking load.
- Design Appraisal Document Number.
- Socket inspection certificate references.
- Individual wire certificate references.
- Sheathing report references.

■ *Section 8* Chains

8.1 Chain grades

8.1.1 Chains to be offshore Grades R3, R3S, or R4 and are to comply with Ch 10,3 and Ch 10,4 of the Rules for Materials, as applicable. Acceptance of other grades will be subject to special consideration.

8.2 Corrosion and wear

8.2.1 A size margin over and above the minimum chain size required to satisfy Rule factor of safety requirements is to be included to allow for the corrosion and wear which can occur over the intended service life of the anchor chain or associated component. The minimum margins shown in Table 10.8.1 are recommended.

Table 10.8.1 Chain size corrosion and wear margins

Region of anchor chain	Margin (mm per year service life, on chain diameter)
Splash zone	0,3
Catenary	0,2
Touchdown zone and sea bed	0,4

NOTES
1. Additional margins greater than those indicated in the Table may be required where chains are subjected to high wear rates.
2. *See* Pt 1, Ch 3,5.6 for acceptance criteria relating to chain size diminution in service.

■ *Section 9* Provisional requirements for fibre ropes

9.1 General

9.1.1 This Section gives provisional requirements for fibre ropes used in positional mooring systems. The requirements apply to fibre ropes incorporated as follows:

(a) Catenary mooring system:
- Fibre rope insert lines, these being confined to the suspended part of the catenary system. Chain or wire rope will be fitted in parts of the anchor leg subject to contact with sea bed or floating unit.

(b) Taut-leg moorings:
- In this case, fibre rope will form the majority of the anchor leg's length. System compliancy will come from the inherent extensibility of the fibre rope. Chain will be fitted at upper and lower parts of the taut leg, where hard contact can occur.
- Special consideration will be given to other types of fibre rope mooring application.

9.2 Design aspects

9.2.1 Fibre ropes and associated fittings are to be of an approved design. The following information to be submitted:

(a) Specifications:
- Rope purchaser's specification.
- Rope design specification.
- Rope manufacturing and testing specification.

(b) Plans:
- Rope, spool piece and other fittings.

(c) Calculations:
- Strength and fatigue of rope and fittings.

(d) Rope particulars:
- Fibre type.
- Diameter of rope.
- Length at specified tension.
- Construction.
- Weight in air and water.
- Sheathing type.
- Terminations.
- Bend limiters.

(e) Rope properties:
- Minimum breaking strength.
- Mean breaking load of rope and coefficient of variation, from tests.
- Axial stiffness values (to cover upper and lower bounds of stiffness).
- Fatigue data (tension-tension and compression).
- Creep.
- Hysteresis.
- Torque/twist.
- Resistance to chemical attack in an offshore environment.
- Long-term degradation.

9.2.2 Factors of safety for fibre rope anchor line elements to be a minimum of 20 per cent higher than the levels given in Section 6 for chain and wire rope materials.

$$\text{Factor of safety} = \frac{\text{Minimum breaking strength}}{\text{Maximum tension}}$$

A reduction factor will require to be applied to the standard designated minimum breaking strength, where the test database for the rope type is statistically small.

9.2.3 The fibre rope section of an anchor leg is not to touch the sea bed in any intact or damaged condition.

9.2.4 Fibre ropes are to be kept sufficiently far below the waterline, and below the connection point on the unit, to avoid any possibility of contact damage.

9.3 Manufacture

9.3.1 Fibre ropes are to be manufactured at a works approved by LR.

9.3.2 Ropes and fittings will be subject to LR survey during manufacture and testing.

9.3.3 A certified ISO 9001/9002 Quality System is to be in place and a quality plan is to be produced and agreed with LR Surveyors.

9.3.4 The ropes and fittings are to be manufactured in accordance with the approved design, standards and procedures.

9.3.5 *See also* the requirements of Ch 10.7 of the Rules for Materials.

Section 10
Anchor points

10.1 Drag embedment anchors – Structural aspects

10.1.1 This sub-Section and 10.2 apply to drag embedment anchors of high holding power type. Proposals for the use of other anchor types will be specially considered.

10.1.2 Anchors are to be of an approved type.

10.1.3 Material selection for drag embedment anchors are, generally, to be in accordance with Pt 4, Ch 2,4, taking the structural category as 'Primary'.

10.1.4 Supporting calculations to verify the structural strength of the anchor for design service loads and for proof test loads are to be submitted.

10.1.5 The anchors are to be manufactured in accordance with the requirements of Chapter 10 of the Rules for Materials.

10.1.6 Anchors are to be subject to proof test loading in the manner laid down in the Rules. The level of proof test loading for positional mooring anchors is 50 per cent of the minimum rated breaking strength of the attached anchor line.

10.1.7 Proof load testing of large fabricated anchors (in excess of 15 tonnes mass) may be waived for classification, subject to the following:

(a) Structural strength of anchor type being verified by finite element analysis procedure.
(b) All main structural welds being subject to non-destructive examination as follows at manufacture:
    - 100 per cent visual.
    - 100 per cent MPI.
    - 100 per cent UT/radiographic, for full penetration welds.

10.1.8 Notwithstanding the above, attention is drawn to the separate requirement of some National Authorities for proof load testing of anchors.

10.2 Drag embedment anchors – Holding capacity

10.2.1 The requirements of 10.1 are also to be considered, in addition to this sub-Section.

10.2.2 Anchors for positional mooring are to be sufficient in number and holding capacity for the intended service. It is the Owner's/Operator's responsibility to ensure adequate anchor holding capacity for each location or holding ground.

10.2.3 The following is to be submitted for information:

- Data, calculations and analysis supporting the selection of anchor.
- Anchor details.
- Test loading at installation.

10.3 Other anchors

10.3.1 Proposals for the use of anchors other than drag embedment type will be specially considered. Reference can be made to Pt 3, Ch 10 and Ch 12 of LR's *Rules and Regulations for the Classification of a Floating Offshore Installation at a Fixed Location*, for requirements applying to other anchor types (e.g., Pile Anchors, Suction Anchor Piles, Gravity Anchors).

Section 11
Fairleads and cable stoppers

11.1 General requirements

11.1.1 Fairleads and stoppers are to be designed to permit free movement of the anchor line in all mooring configurations and designed to prevent excessive bending and wear of the anchor lines.The hardness of fairleads and chain stoppers, where in contact with the anchor line, should be softer than the anchor line. In general, the anchor line should not be in contact with any welds but, where this is not possible, the welds are to be ground flush and are to be softer than the anchor line.

11.1.2 The minimum operating range of the fairlead to be considered in conjunction with the design load is shown in Fig. 10.11.1.

11.1.3 Fairleads and stoppers and their supporting structures are to be designed for a load equivalent to the rated minimum break strength of the anchor line. Where applicable, side loads due to friction in the bearings need to be accounted for in the design, *see also* 11.1.8.

11.1.4 The maximum permissible stresses are to be in accordance with Pt 4, Ch 5,2.1.1(c).

11.1.5 Materials and steel grades are generally to comply with the requirements given in Pt 4, Ch 2 for primary structures.

11.1.6 Chain cable fairleads are to have a minimum of five pockets.

11.1.7 It is recommended that wire rope fairleads have a minimum diameter of 16 times the wire rope diameter.

11.1.8 Special consideration will be given to permissible stresses where the chain is of downgraded quality.

Note

There have been cases of closing plates on the fairlead shaft coming loose due to corrosion of the threads of the securing bolts, resulting in serious damage to the fairlead arrangements and the complete jamming of the fairlead and chain. Consequently, the securing bolts should also be checked to ensure that the bolt material does not corrode preferentially should the sacrificial anode system fail to function in way of the fairlead.

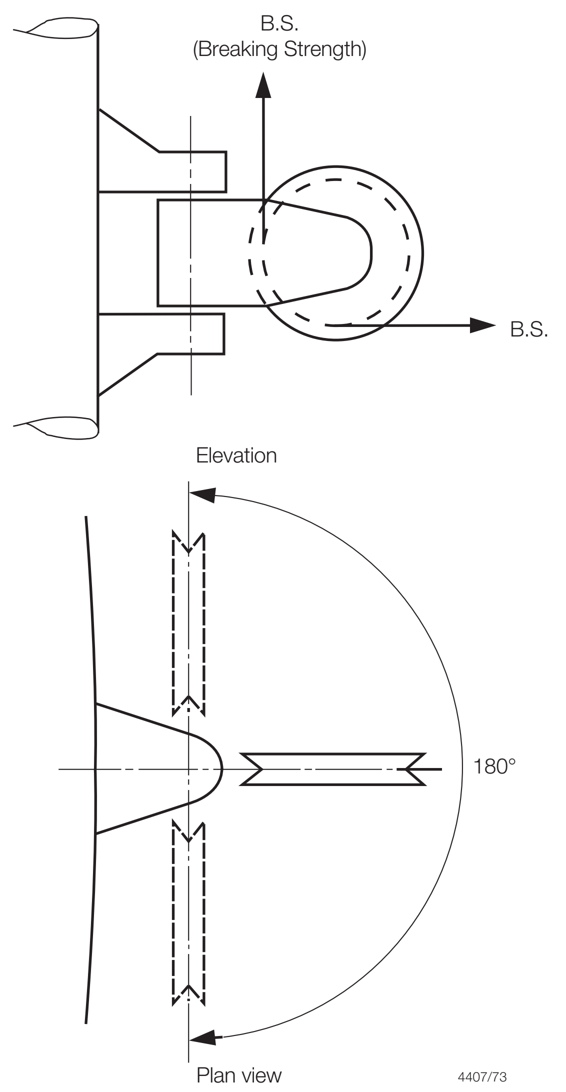

Fig. 10.11.1 Minimum operating range of fairlead

■ *Section 12*
Anchor winches and windlasses

12.1 General

12.1.1 This Section applies to winches and windlasses designed to actively control anchor line tensions in service, or to release anchor lines in an emergency.

12.1.2 Special consideration will be given to requirements for winches and windlasses for passive mooring systems or permanent mooring systems.

12.1.3 Machinery items are to be constructed to recognised design Codes and Standards. The relevant requirements of Part 5 may be used as guidance for small and simple equipment, but for larger and more complex designs, special analysis techniques such as finite element methods (or equivalent) are considered to be more appropriate.

12.1.4 Machinery items are to be installed and tested in accordance with the relevant requirements of Part 5. For electrical and control equipment, *see* Section 13.

12.2 Materials

12.2.1 Materials are to comply with the Rules for Materials. Alternatively, materials which comply with National or proprietary specifications may be accepted, provided that these specifications give reasonable equivalence to the requirements of the Rules for Materials, or are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of the Rules for Materials.

12.2.2 For the selection of material grades, individual components of anchor winches and windlasses are to be categorised as primary or secondary.

12.2.3 Components where the failure would result in the loss of a primary function of the winch or windlass are considered to be ‘primary components’, *see also* 12.2.5.

12.2.4 All other components where the failure would not result in the loss of a primary function of the winch or windlass are to be categorised as ‘secondary components’.

12.2.5 Primary components which are designed with an adequate degree of redundancy in their operation will be specially considered and may be categorised as secondary.

12.2.6 Material grades for all components are in general related to the thickness of the material, the structural category and the minimum design air temperature and are to be selected to provide adequate notch toughness.

12.2.7 Material grades for welded plate components are in general to comply with Pt 4, Ch 2,4. For plates with a thickness greater than 50 mm but not exceeding 100 mm, Grade E or EH may be accepted for a design air temperature down to minus 15°C. For thicker plates and/or lower design temperature the steel grades will be specially considered.

12.2.8 Material grades for components which are not subject to welding will be specially considered.

12.2.9 Castings and forgings are to comply with Chapters 4 and 5 of the Rules for Materials respectively and the requirements for notch toughness in relation to the design air temperature will be specially considered.

12.2.10 Non-ductile materials are not to be used for torque transmitting items or for those elements subject to tensile/bending stresses.

12.2.11 Spheroid graphite iron castings are to comply with Ch 7,3 of the Rules for Materials, Grades 370/17 or 400/12, or to an equivalent National Standard.

12.2.12 The use of grey iron castings will be subject to special consideration. Where approved, they are to comply with the requirements of Ch 7,2 of the Rules for Materials. This material is not to be used for gear components.

12.2.13 Brake lining materials are to be compatible with operating environmental conditions.

12.3 Brakes

12.3.1 Each anchor winch or windlass is required to have one primary braking system and one secondary braking system. The two systems are to operate independently. The requirements of 12.5 are to be complied with.

12.3.2 The braking action of the motor unit may be used for secondary braking purposes where the design is suitable.

12.3.3 A residual braking force of at least 50 per cent of the maximum braking force required by 12.5.1 is to be immediately available and automatically applied in the event of a power failure.

12.4 Stoppers

12.4.1 If the winch motor is to be used as a secondary brake then a stopper is to be provided to take the anchor line load during maintenance of the primary brake.

12.4.2 The stopper may be one of two different types – a pawl stopper fitted at the cable lifter/drum shaft, or a stopper acting directly on the anchor line.

12.4.3 Where the stopper acts directly on the cable, its design is to be such that the cable will not be damaged by the stopper at a load equivalent to the rated breaking strength of the cable.

12.4.4 *See also* 13.3.1 and 13.3.2, for stopper control station requirements, and 13.5.6, for emergency release of stoppers.

12.5 Winch/windlass performance

12.5.1 The primary brake is required to hold a static load equal to the minimum break strength of the anchor line (at the intended outer working layer of wire rope on storage drum winches). The static load capacity of the primary brake can be reduced to 80 per cent of that value when a stopper capable of holding 100 per cent of the breaking strength of the line is fitted.

12.5.2 The secondary brake is required to hold a static load equal to 50 per cent of the minimum breaking strength of the anchor line.

12.5.3 The anchor winch or windlass is to have adequate dynamic braking capability. The two brake systems in joint operation are to be capable of fully controlling, without overheating, the anchor lines during:

- all anchor handling operations;
- adjustment of anchor line tensions. (This is particularly relevant where the mooring system has been designed and sized on the basis of active adjustment of anchor lines in extreme conditions, to minimise line tensions).

12.5.4 *See also* 13.3 for control of winches, windlasses, stoppers and pawls, and 13.5 for brake fail-safe requirements and standby power for operation of brakes and release of stoppers in the event of a failure of normal power supply.

12.5.5 Means are to be provided to enable the anchor lines to be released from the unit after loss of main power.

12.5.6 The pulling force of the winches or windlasses is to be sufficient to carry out anchor pre-loading on location, to the necessary level. A minimum low-speed pull equal to 40 per cent of the anchor line breaking strength is recommended.

12.6 Strength

12.6.1 Design load cases for the winch or windlass assembly and the stopper, when fitted, are given in Table 10.12.1. The associated maximum allowable stresses are to be based on the factors of safety given in Table 10.12.2.

Table 10.12.1 Design load cases

Load case	Condition	Anchor line load percentage of break strength
1	Winch braked	100% (*See* Note)
2	Stopper engaged	100%
3	Winch pulling	40% or specified duty pull if greater

NOTE
Where a stopper is fitted, the anchor line load in Case 1 may be taken as the brake slipping load, but is not to be less than 80 per cent of the break strength of the anchor line.

12.7 Testing

12.7.1 Works' tests are to be carried out at the manufacturer's works in the presence of the Surveyor, on at least one of the winches or windlass units out of the total outfit for the unit. The tests to be carried out are given in Table 10.12.3. Alternatively, where a prototype winch has been suitably tested, consideration will be given to the acceptance of these results.

12.7.2 The residual braking capability is to be verified in accordance with 12.5.4.

Table 10.12.2 Load case factors of safety

Stress	Load case	
	1 and 2	3
	Factor of safety	
Shear Tension, compression, bending Combined	1,89 1,25 1,11	2,5 1,67 1,43

NOTES
1. Factors of safety relate to tensile yield stress.
2. Combined stress = $\sqrt{\sigma_X{}^2 + \sigma_Y{}^2 - \sigma_X\sigma_Y + 3\tau^2}$

   Where σ_X and σ_Y are the combined axial and bending stresses in the X and Y directions respectively and τ is the combined shear stress due to torsion and/or bending in the X–Y plane.

Table 10.12.3 Winch/windlass tests

Test	Test load
Static brake – Primary	100% anchor line break strength (or 80% where stopper fitted. *See* 12.5.1)
Static brake – Secondary	50% anchor line break strength
Stopper (where fitted)	100% anchor line break strength
Motor stall test	Specified stall load

12.7.3 Each winch or windlass is to be tested on board the vessel in the presence of the Surveyor, to demonstrate that all main aspects including dynamic brakes function satisfactorily. The proposed test programme is to be submitted.

12.8 Type approval

12.8.1 Winches or windlasses may be type approved in accordance with LR's Type Approval Scheme. Where this Type Approval is obtained, the requirements of 12.7.1 may not be applicable.

■ *Section 13*
Electrical and control equipment

13.1 General

13.1.1 The electrical installation is to be designed, constructed and installed in accordance with the relevant requirements of Pt 6, Ch 2.

13.1.2 Control, alarm and safety systems are to be designed, constructed and installed in accordance with the relevant requirements of Pt 6, Ch 1, together with the requirements of 13.2 to 13.4.

13.1.3 Reference should be made to the general requirements of Section 14 for thruster-assisted positional mooring systems.

13.2 Controls, indications and alarms

13.2.1 Adequate control, indication and alarm systems are to be provided to ensure satisfactory operation of the positional mooring system.

13.2.2 A suitable central control station is to be provided.

13.2.3 Where additional local control stations are provided, means of direct communication between the local and central control stations are to be arranged.

13.2.4 Indication of the following, as applicable, is to be provided at the central control station and, where local control is provided, at the local control station:
(a) Position of unit.
(b) Heading of unit.
(c) Anchor line tensions.
(d) Wind speed and directions.

13.2.5 Alarms are to be provided for the following fault conditions, as applicable:
(a) Deviation from positional limits.
(b) Deviation from heading limits.
(c) Deviation from anchor line tension limits (high and low).
(d) Gyro compass fault.
(e) Position reference system fault.
(f) Wind speed and direction indicator fault.
(g) Control computer system fault.

13.3 Control stations

13.3.1 The operation of winches, windlasses and associated brakes, chainstoppers and pawls is to be controlled locally from weather protected control stations which provide good visibility of the equipment and associated anchor handling operations.

13.3.2 A central control station, which may be located on the bridge or a separate manned control room, is to be provided from which brakes, chainstoppers and pawls can be remotely released.

13.3.3 For each anchor winch, the respective local control station is to be provided with a means of indicating the following:
(a) Line tension.
(b) Length of line paid out.
(c) Line speed.

13.3.4 The indication required by 13.3.3(a) and (b) is to be repeated to the central control station and in addition a means of indicating the following is to be provided at this position:
(a) Mooring patterns and anchor line catenaries.
(b) Status of winch operation.
(c) Position and heading, *see also* 13.5.7.
(d) Gangway angle and extension, when applicable.
(e) Riser angle, when applicable.
(f) Wind speed and direction, *see also* 13.5.10.

13.3.5 Means of voice communication are to be provided between the central control station, each local control station and anchor handling vessels, when applicable.

13.4 Alarms

13.4.1 Alarms are to be provided at the local and central control stations for the following fault conditions:
(a) Excessive line tension.
(b) Loss of line tension.
(c) Excessive gangway angle and extension, when applicable.
(d) Excessive riser angle, when applicable.

13.4.2 Alarms are to be provided adjacent to the winches and windlasses to warn personnel prior to and during any remote operation.

13.4.3 Alarms are to be provided at the central control station for the following fault conditions:
(a) When the unit deviates from its predetermined area of operation.
(b) When the unit deviates from its predetermined heading limits.
These alarms are to be adjustable but should not exceed specified limits. Arrangements are to be provided to fix and identify their set points.

13.5 Controls of winch and windlass systems

13.5.1 This sub-Section is applicable to mooring systems incorporating winches, windlasses, etc., which are used to actively control and adjust anchor line tensions in service, or to release anchor lines in an emergency.

13.5.2 Adequate controls are to be provided at the local control station for satisfactory operation of the winch(es).

13.5.3 The braking system is to be arranged so that the brakes, when applied, are not released in the event of a failure of the normal power supply.

13.5.4 Standby power is to be provided to enable winch brakes to be released within 15 seconds in an emergency. The release arrangements are to be operable locally at each winch and from the central control position, and are to be such that the entire anchor line can be lowered in a controlled manner.

13.5.5 The standby power is to be such that during lowering of the anchor line it is possible to apply the brakes once and then release them again in a controlled manner.

13.5.6 Standby power is to be provided so that any anchor line stoppers or pawl mechanisms may be released from either the local or central control stations up to a line tension equal to the minimum rated break strength of the anchor line. These mechanisms are to be capable of release at the maximum angles of heel and trim under the damage stability and flooding conditions for which the unit is designed.

13.5.7 At least one position reference system and one gyrocompass or equivalent is to be provided, when applicable, to ensure the specified area of operation and heading deviation can be effectively monitored.

13.5.8 Position reference systems are to incorporate suitable position measurement techniques which may be by means of acoustic devices, radio, radar, taut wire, riser angle, gangway extension and angle or other acceptable means, depending on the service conditions for which the unit is intended.

13.5.9 A vertical reference sensor is to be provided, if applicable, to measure the pitch and roll of the unit.

13.5.10 Means are to be provided to ascertain the wind speed and direction acting on the unit.

■ *Section 14* Thruster-assisted positional mooring

14.1 General

14.1.1 Where the positional mooring system is assisted by thrusters, as defined in Section 4, units complying with the requirements of this Section together with the requirements in Section 15 will be eligible for one of the following supplementary class notations as specified in 1.2:

TA(1) *See* 15.1
TA(2) *See* 15.2
TA(3) *See* 15.3

14.1.2 Machinery items are to be constructed, installed and tested in accordance with the relevant requirements of Part 5 together with the requirements of 14.2 and Section 15.

14.2 Thrust units

14.2.1 Thruster installations are to be designed to minimise potential interference with other thrusters, sensors, hull or other surfaces which could be encountered in the service for which the unit is intended.

14.2.2 Thruster intakes are to be located at sufficient depth to reduce the possibility of ingesting floating debris and vortex formation.

14.2.3 Steerable thrusters and thrusters having variable pitch propellers are to be provided with two independent supplies of motive power to the pitch and direction actuating mechanisms.

14.2.4 Each thruster unit is to be provided with a high power alarm. The setting of this alarm is to be adjustable and below the maximum thruster output.

14.2.5 The response and repeatability of thrusters to changes in propeller pitch or propeller speed/direction of rotation are to be suitable for maintaining the area of operation and the heading deviation specified.

14.2.6 The thrust unit housing is to be tested at a hydraulic pressure of not less than 1,5 times the service immersion head of water or 1,5 bar (1,5 kgf/cm^2), whichever is the greater.

14.3 Electrical equipment

14.3.1 The electrical installation is to be designed, constructed and installed in accordance with the relevant requirements of Pt 6, Ch 2, together with the requirements of 14.3.3 to 14.3.8, and the relevant requirements of Section 15.

14.3.2 Where the thruster units are electrically driven, the relevant requirements, including surveys, defined in Pt 6, Ch 2,15 are to be complied with.

14.3.3 The total generating capacity is to be in accordance with 15.1.3, 15.2.8 and 15.3.8, as applicable.

14.3.4 Where the electrical power requirements are supplied by one generator set, on loss of power there is to be provision for automatic starting and connection to the switchboard of a standby set and automatic restarting of essential auxiliary services. For other requirements relevant to particular thruster-assisted class notations, *see* Section 15.

14.3.5 An alarm is to be initiated at the thruster-assisted positioning control station(s) when the total electrical load of all operating thruster units exceeds a pre-set percentage of the running generator(s) capacity. This alarm is to be adjustable between 50 and 100 per cent of the full load capacity, having regard to the number of electrical generators in service.

14.3.6 The number and ratings of power transformers are to be sufficient to ensure full load operation of the thruster-assisted positioning system even when one transformer is out of service. This does not require duplication of a transformer provided as part of a transformer/silicon controlled rectifier (SCR) drive unit.

14.3.7 Thruster auxiliaries, control computers, reference systems and environmental sensors are to be served by individual circuits. Services that are duplicated are to be separated throughout their length as widely as is practical and without the use of common feeders, transformers, converters, protective devices or control circuits.

14.3.8 Where the auxiliary services and positioning mooring thrusters are supplied from a common source, the following requirements are to be complied with:

(a) The voltage regulation and current sharing requirements defined in Pt 6, Ch 2,8 are to be maintained over the full range of power factors that may occur in service.
(b) Where SCR converters are used to feed the thruster motors, and the instantaneous value of the line-to-line voltage wave-form on the a.c. auxiliary system busbars deviates by more than 10 per cent of $\sqrt{2}$ times the r.m.s. voltage from the instantaneous value of the fundamental harmonic, the essential auxiliary services are to be capable of withstanding the additional temperature rise due to the harmonic distortion. Control, alarm and safety equipment is to operate satisfactorily with the maximum supply system wave-form distortion, or be provided with suitably filtered/converted supplies.
(c) When the control system incorporates volatile memory it is to be supplied via uninterruptible power supplies provision for automatic starting and connection to the (UPS), *see also* Pt 6, Ch 2,9.3.

14.4 Control engineering systems – Additional requirements

14.4.1 The control engineering systems are to be designed in accordance with the relevant requirements of Section 13 together with the additional requirements of 14.4.2 to 14.4.3 and the relevant requirements of Section 15.

14.4.2 Indication of the following is to be provided at each station from which it is possible to control the thruster-assisted positioning system, as applicable:

- The heading and location of the vessel relative to the desired reference point or course.
- Vectorial thrust output, individual and total.
- Operational status of position reference systems and environmental sensors.
- Environmental conditions, e.g., wind speed and direction.
- Availability status of standby thruster units.

14.4.3 Alarms are to be provided for the following fault conditions where applicable:

- When the unit deviates from its predetermined area of operation.
- When the unit deviates from its predetermined heading limits.
- Position reference system fault (for each reference system).
- Gyrocompass fault.
- Vertical reference sensor fault.
- Wind sensor fault.
- Taut wire excursion limit.
- Automatic changeover to a standby position reference system or environmental sensor.
- Control computer system fault.
- Automatic changeover to a standby control computer system, *see* 15.3.3.

14.4.4 Suitable processing and comparative techniques are to be provided at the central control station to validate the control system inputs from position and other sensors, to ensure optimum performance of the thruster-assisted mooring system.

14.4.5 Abnormal signal errors revealed by the validity checks required by 14.4.4 are to operate alarms.

14.4.6 The control system for thruster-assisted positioning operation is to be stable throughout its operational range and is to meet the specified performance and accuracy criteria.

14.4.7 Automatic controls are to be provided to maintain the desired heading of the unit.

14.4.8 The deviation from the desired heading is to be adjustable, but is not to exceed the specified limits. Arrangements are to be provided to fix and identify the set point for the desired heading.

14.4.9 Sufficient instrumentation is to be fitted at the central control station to ensure effective control and indicate that the system is functioning correctly, *see* 14.4.2.

■ *Section 15* Thruster-assist class notation requirements

15.1 Notation TA(1)

15.1.1 For assignment of the notation **TA(1)**, in accordance with Section 4, the applicable requirements of Sections 13 and 14, together with 15.1.2 to 15.1.3, are to be complied with.

15.1.2 Centralised automated manual control of the thrusters is to be provided to supplement the positional mooring system. The manual control system is to provide output signals to the thrusters via the manual controller to change the speed, pitch and azimuth angle, as applicable, as indicated at the central control station, *see* 13.2.

15.1.3 For electrically driven thruster systems, the total generating capacity of the electrical system is to be not less than the maximum dynamic positioning load together with the maximum auxiliary load. This may be achieved by parallel operation of two or more generating sets, provided the requirements of Pt 6, Ch 2,2.2 are complied with.

15.2 Notation TA(2)

15.2.1 For assignment of the notation **TA(2)**, in accordance with Section 4, the applicable requirements of Sections 13 and 14, together with 15.2.2 to 15.2.8, are to be complied with.

15.2.2 Automatic and manual control systems are to be provided to supplement the positional mooring systems and arranged to operate independently so that failure in one system will not render the other system inoperative, *see also* 15.1.2 for manual control.

15.2.3 The automatic control system is to utilise automatic inputs from the position reference system, the environmental sensors and line tensions, and automatically provide output signals to the thrusters to change the speed, pitch and azimuth angle, as applicable, such that the line tensions are optimised.

15.2.4 In the event of a failure of a reference or environmental sensor, the control systems are to continue to operate on signals from the remaining sensors without manual intervention.

15.2.5 In the event of line failure or failure of the most effective thruster, the unit is to be capable of maintaining its predetermined area of operation and desired heading in the environmental conditions for which the unit is designed and/or classed.

15.2.6 Control, alarm and safety systems are to incorporate a computer-based consequence analysis which may be continuous or at predetermined intervals and is to analyse the consequence of predetermined failures to verify that the anchor line tensions and position/heading deviations remain within acceptable limits. In the event of a possible hazardous condition arising as a result of the consequence analysis, an alarm is to be initiated at the central control station.

15.2.7 The area of operation is to be adjustable, but is not to exceed the specified limits, which are to be based on a percentage of water depth, or if applicable a defined absolute surface movement. Arrangements are to be provided to fix and identify the set point for the area of operation.

15.2.8 For electrically driven thruster systems, the following requirements are to be complied with:
(a) Generating capacity, as defined in 15.1.3.
(b) With one generating set out of action, the capacity of maximum positioning load with the most effective thruster inoperative, together with the essential services defined by Pt 6, Ch 2,1.5.
(c) Where generating sets are arranged to operate in parallel, the supplies to essential services are to be protected by the tripping of non-essential loads as required by Pt 6, Ch 2,6.9 and additionally, on loss of a running generator, a reduction in thrust demand may be accepted, provided the arrangements are such that a sufficient level of dynamic position capability is retained to permit the three degrees of manoeuvrability of the unit.
(d) Indication of absorbed electrical power and available on-line generating capacity is to be provided at the main thruster-assisted positioning control station, *see* 14.4.1.
(e) Means are to be provided to prevent starting of thruster motors until sufficient generating capacity is available.

15.3 Notation TA(3)

15.3.1 For assignment of the notation **TA(3)**, in accordance with Section 4, the applicable requirements of Sections 13 and 14, together with 15.2.3 to 15.2.8 and 15.3.2 to 15.3.9, are to be complied with.

15.3.2 Two automatic control systems are to be provided and arranged to operate independently so that failure in one system will not render the other system inoperative.

15.3.3 In the event of failure of the working system, the standby automatic control system is to be arranged to change over automatically without manual intervention and without any adverse effect on the vessel's station-keeping capability. The automatic changeover is to initiate an alarm.

15.3.4 At least two position reference systems as defined by 13.5.8, and two gyrocompasses or equivalent, are to be provided.

15.3.5 At least two of each of the sensors as required by 13.5.9 and 13.5.10 are to be provided.

15.3.6 When two voyage recording systems are deployed, their outputs are to be compared and an alarm raised when a significant difference occurs.

15.3.7 The arrangement is to be verified by means of a Failure Modes and Effects Analysis (FMEA). Such components may include, but not be restricted to, the following:

- Mooring systems.
- Prime movers, e.g., auxiliary engines.
- Generators and the excitation equipment.
- Switchgear.
- Pumps.
- Thrusters.
- Fans.
- Valves, where power actuated.

15.3.8 Control, alarm and safety systems are to incorporate a computer-based consequence analysis which may be continuous or at predetermined intervals and is to analyse the consequence of predetermined failures to verify that position and heading deviation remain within acceptable limits. In the event of a possible hazardous condition being indicated from the consequence analysis, an alarm is to be initiated.

■ *Section 16* Trials

16.1 General

16.1.1 Before a new installation (or any alteration or addition to an existing installation) is put into service, trials are to be carried out. These trials are in addition to any acceptance tests which may have been carried out at the manufacturer's works and are to be based on the approved test schedules list as required by 1.4.1(d).

16.1.2 The suitability of the positional mooring and/or thruster-assisted positional mooring system is to be demonstrated during sea trials, observing the following:

(a) Response of the system to simulated failures of major items of control and mechanical equipment, including loss of electrical power.

(b) Response of the system under a set of predetermined manoeuvres for changing:
- Location of area of operation;
- Heading of the unit.

(c) Automatic thruster control and line tension optimisation.

(d) Monitoring and consequence analyses.

(e) Simulation of line breakage and damping.

(f) Continuous operation of the thruster-assisted positional mooring system over a period of four to six hours.

16.1.3 Two copies of the test schedules, as required by 1.4.1(d), signed by the Surveyor and Builder, are to be provided on completion of the survey. One copy is to be placed on board the unit and the other submitted to LR.

Section 1 Rule application

1.1 General

1.1.1 Masts, derrick posts, crane pedestals and similar supporting structures to equipment are classification items, and the scantlings and arrangements are to comply with the additional requirements of this Chapter.

1.1.2 Certain lifting appliances on special purpose units which are considered an essential feature of the unit are to be included in the classification of the unit. Elsewhere, classification of lifting appliances is optional and may be assigned at the request of the Owner on compliance with the appropriate requirements.

1.1.3 Where the lifting appliance is considered to be an essential feature of a classed unit, the special feature class notation **LA** will, in general, be mandatory.

1.2 Masts, derrick posts and crane pedestals

1.2.1 The scantlings of masts and derrick posts, intended to support derrick booms, and of crane pedestals are to comply with the requirements of LR's *Code for Lifting Appliances in a Marine Environmen*t (hereinafter referred to as LAME Code).

1.2.2 In addition to the information and plans requested in LR's LAME Code, the following details are to be submitted:

(a) Details of deckhouses or other supports for the masts, derrick posts or crane pedestals, together with details of the attachments to the hull structure.

(b) Details of any reinforcement or additional supporting material fitted to the hull structure in way of the mast, derrick post or crane pedestal.

1.2.3 Masts, derrick posts or crane pedestals are to be efficiently supported and, in general, are to be carried through the deck and satisfactorily scarfed into transverse or longitudinal bulkheads, or equivalent structure. Alternatively, the mast, derrick posts or crane pedestals may be carried into a deckhouse or equivalent structure, in which case the house is to be of substantial construction. Proposals for other support arrangements will be specially considered.

1.2.4 Deck plating and underdeck structure are to be reinforced under masts, derrick posts and crane pedestals. Where the deck is penetrated the deck plating is to be suitably increased locally.

1.2.5 The permissible stresses in the support structure are to be in accordance with Pt 4, Ch 5,2.

1.3 Lifting appliances

1.3.1 Offshore units fitted with lifting appliances built in accordance with LR's LAME Code in respect of structural and machinery requirements will be eligible to be assigned special features class notations as listed in Table 11.1.1. The notation will be retained so long as the appliances are found upon examination at the prescribed surveys to be maintained in accordance with LR's requirements.

Table 11.1.1 Special features class notations associated with lifting appliances

Cranes on offshore units	**PC**	Optional notation. Indicates that the unit's main deck cranes are included in class
Lifts	**PL**	Optional notation. Indicates that the unit's personnel lifts are included in class
Lifting appliances forming an essential feature of the unit e.g. Cranes on crane barges or units, lifting arrangements for diving on diving support units, etc.	**LA**	Mandatory notation. Indicates that the lifting appliance is included in class

1.4 Crane boom rests

1.4.1 With the crane boom in the stowed position, the structure of the crane boom support structure is to be designed for the maximum reaction forces in any operating condition, taking into account the maximum design environmental loadings and inertia forces due to unit motions.

1.4.2 The crane boom support structure is also to be verified in the emergency condition defined in Ch 8,1.4.

1.4.3 The permissible stresses in the crane boom support structure and the deck structure below are to be in accordance with Pt 4, Ch 5,2.

1.5 Runway beams

1.5.1 Runway beams are to be designed and tested *in situ* in accordance with a recognised Standard and marked with the safe working load, *see also* Appendix A.

1.6 Lifting padeyes

1.6.1 Padeyes attached to the main structure which are to be used with a rated lifting appliance are to be proof tested after installation and marked with the safe working load (SWL). The proof load is not to be less than 1,5 x SWL.

1.6.2 Lifting lugs are to be permanently marked with the SWL, tested after installation and NDE to the Surveyor's satisfaction. In agreement with LR, testing and NDE of lifting lugs with SWL < 1 tonne may be by sampling, provided design calculations can demonstrate a factor of safety greater than 2.

1.7 Access gangways

1.7.1 Pedestals and similar structures supporting installed gangways used for access to adjacent fixed installations are classification items and the scantlings and arrangements are to comply with the general requirements for crane pedestals and support structure in 1.2.

1.7.2 The gangway is to comply with the relevant statutory Regulations of the National Administration of the country in which the unit is registered and/or in which it is to operate and design calculations for the supporting structure are to be submitted.

Section

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter apply to rigid and flexible risers, together with associated components, between the pipeline end manifold connection and the connection to the unit, *see* 1.4.2. The requirements of this Chapter are considered to be supplementary to the requirements in the relevant Parts of the Rules.

1.1.2 The requirements also apply to surface floating and suspended flexible loading hoses (as appropriate).

1.1.3 Submarine steel pipelines are to comply with the requirements contained in internationally recognised Codes and Standards.

1.1.4 The riser system will be considered for Classification on the basis of operating constraints and procedures specified by the Owner and recorded in the Operations Manual.

1.1.5 Risers may be arranged separately or in connected bundles comprising production risers together with other elements.

1.2 Class notations

1.2.1 The Regulations for classification and the assignment of class notations are given in Pt 1, Ch 2, to which reference should be made.

1.2.2 Offshore units connected to product riser systems which comply with the requirements of this Chapter will be eligible for the assignment of the special features class notation **PRS**.

1.2.3 The service limits on which approval of the riser system has been based are to be included in the Operations Manual, *see* 2.5.

1.3 Definitions

1.3.1 The definitions in this Chapter are stated for Rule application only, and may not necessarily be valid in any other context.

1.3.2 **Riser system**. The riser together with its supports, component parts and ancillary systems such as corrosion protection, mid water arch, bend stiffeners, buoyancy modules, bend restrictors, bend stiffener latching mechanisms, etc.

1.3.3 **Riser**. A subsea flexible hose or rigid pipe leading down from the connection on the unit to a sea bed termination structure. Risers may have a variety of functions including liquid and gas export, water injection, chemical injection and controls, etc.

1.3.4 **Floating pipe**. A surface pipe between the single-point mooring or buoy and the ship manifold. The floating pipe is normally permanently attached to the single-point mooring.

1.3.5 **Riser support**. Any structural item used for connecting a part of the riser system to the unit.

1.3.6 **Riser components**. Valves, connections, etc., and similar apparatus incorporated in the riser system.

1.4 Scope

1.4.1 The following additional topics applicable to the special features class notation are covered by this Chapter:
- Welded steel risers.
- Flexible risers.
- Floating hoses.
- Pig traps.
- Valves, controls and fittings.
- Safety devices.
- Coverings and protection.
- Cathodic protection system.

1.4.2 Unless agreed otherwise with LR, the Rules consider the following as the main boundaries of the riser system:
- Any part of the riser system as defined in 1.3.2 from the sea bed termination to the first riser connector valves on the unit.
- The riser connector valves will normally be considered part of the offshore unit, unless agreed otherwise with LR.

1.5 Damage protection

1.5.1 Wherever possible, risers should be protected from collision damage either by suitable positioning within the unit or by protective structure provided for this purpose.

1.5.2 The risk of damage arising from impact loads should form an integral part of the riser assessment. The assessment should evaluate the risk and consequences to the installation of a release of hydrocarbon from the riser.

1.5.3 Design of the riser system should consider the avoidance of collisions between individual risers and anchor lines, etc., with the positioning system intact and in a single fault damaged state under the appropriate environmental conditions. Contact may be allowed in a single fault damaged state provided special external armoury is fitted to the risers in the interference regions, or where appropriate calculations and/or tests indicate that no damage to the risers will occur.

1.5.4 Risers designed to be capable of rapid release should not be damaged in the course of such release, nor should they inflict critical damage on other components.

1.6 Buoyancy elements

1.6.1 Where subsea buoyant vessels are provided as an inherent part of the riser system design, the requirements of Pt 3, Ch 2,2.3 of the *Rules and Regulations for the Classification of a Floating Offshore Installation at a Fixed Location* are to be complied with.

1.6.2 The loss of buoyancy of any one element is not to affect adversely the integrity of the riser system.

1.7 Emergency shut-down (ESD) system

1.7.1 An ESD system is to be provided to riser systems in accordance with Pt 7, Ch 1. This requirement is generally not applicable to conventional surface floating and suspended flexible loading hoses.

1.7.2 An ESD system philosophy should be developed for the installation based on appropriate hazard and safety assessments. Due consideration is to be given to the sequence of events in relation to overall installation safety.

1.7.3 To limit the quantity of flammable or toxic substances escaping in the event of damage to a riser, emergency shut-down valves are to be fitted. The valves and their control mechanisms should be positioned to offer the maximum protection to the unit in the event of damage.

1.7.4 Facilities are to be provided to make it possible at all times to isolate risers by means of valves.

1.7.5 Where appropriate, rapid disconnection of risers must be possible from at least one location. The assessment of how many locations to be provided, and where they should be situated, is to be based on the evaluation of various accident scenarios. Suitable fail-safe measures are to be provided to prevent inappropriate or inadvertent disconnection.

1.8 Recognised Codes and Standards

1.8.1 In general, the requirements in this Chapter are based on internationally recognised Codes and Standards for riser systems, as defined in Appendix A. Other Codes and National Standards may be used after special consideration and prior agreement with LR. When considered necessary, additional Rule requirements are also stated in this Chapter.

1.8.2 The agreed Codes and Standards may be used for design, construction and installation, but the additional requirements stated in the Rules are to be complied with. Where there is any conflict, the Rules will take precedence over the Codes or Standards.

1.8.3 The mixing of Codes or Standards for each equipment item or system is to be avoided. Deviation from the Code or Standard must be specially noted in the documentation and approved by LR.

1.8.4 Where National Administrations have specific requirements regarding riser systems, it is the responsibility of the Owner and Operators to comply with such Regulations.

1.9 Equipment categories

1.9.1 The approval and certification of riser systems are to be based on equipment categories agreed with LR.

1.9.2 Riser systems, including their associated components and valves, are to be divided into equipment Categories **1A**, **1B** and **II**, depending on their complexity of manufacture and their importance with regard to the safety of personnel and the installation and their possible effect on the environment.

1.9.3 The following equipment categories are used in the Rules:

1A Equipment of primary importance to safety, for which design verification and survey during fabrication are considered essential. Equipment in this category is of complicated design/manufacture and is not normally mass produced.

1B Equipment of primary importance to safety, for which design verification and witnessing the product quality are considered essential. Equipment in this category is normally mass produced and not included in Category **1A**.

II Equipment related to safety, which is normally manufactured to recognised Codes and Standards and has proven reliability in service, but excluding equipment in Category **1A** and **1B**.

1.9.4 A guide to equipment and categories is given in Appendix A. A full list of equipment categories for the riser system is to be agreed with LR before manufacture. Minor equipment components need not be categorised.

1.10 Equipment certification

1.10.1 Equipment is to be certified in accordance with the following requirements:

(a) **Category 1A**:
- Design verification and issue of certificate of design strength approval.
- Pre-inspection meeting at the suppliers with agreement and marking of quality plan and inspection schedule.
- Survey during fabrication and review of fabrication documentation.
- Final inspection with monitoring of function/ pressure/load tests and issue of a certificate of conformity.

(b) **Category 1B**:
- Design verification and issue of certificate of design strength approval, where applicable, and review of fabrication documentation.
- Final inspection with monitoring of function/ pressure/load tests and issue of certificate of conformity.

(c) **Category II**:
- Supplier's/manufacturer's works certificate giving equipment data, limitations with regard to the use of the equipment and the supplier's/manufacturer's declaration that the equipment is designed and fabricated in accordance with recognised Standards or Codes.

1.10.2 All equipment recognised as being of importance for the safety of personnel and the riser system is to be documented by a data book.

1.11 Fabrication records

1.11.1 Fabrication records are to be made available for Categories **1A** and **1B** equipment for inspection and acceptance by LR Surveyors. These records should include the following:
- Manufacturer's statement of compliance.
- Reference to design specification and plans.
- Traceability of materials.
- Welding procedure tests and welders' qualifications.
- Heat treatment records.
- Records/details of non-destructive examinations.
- Load, pressure and functional test reports.

1.12 Site installation of riser systems

1.12.1 The installation of riser systems is to be controlled by LR in accordance with the following principles:
- All Category **1A** and **1B** equipment, when delivered to site, is to be accompanied by a certificate of design strength approval and an equipment certificate of conformity and all other documentation.
- All Category **II** equipment, delivered to site, is to be accompanied by equipment data and a works' certificate.
- Control and follow-up of non-conformities/deviations specified in design certificates and certificate of conformity.
- Ongoing survey and final inspection of the installed riser system.
- Monitoring of functional tests after installation and connection to the unit in accordance with an approved test programme.
- Issue of site installation report.

1.13 Maintenance and repair

1.13.1 It is the Owner's/Operator's responsibility to ensure that an installed riser system is maintained in a safe and efficient working condition in accordance with the manufacturer's and design specification.

1.13.2 When it is necessary to repair or replace components of a riser system, any repaired or spare part is to be subject to the equivalent certification as the original, *see* 10.2.

1.14 Plans and data submissions

1.14.1 Plans, calculations and data are to be submitted as required by the relevant Parts of the Rules together with the additional plans and information listed in this Chapter.

■ *Section 2* Plans and data

2.1 General

2.1.1 Sufficient plans and data are to be submitted to enable the design to be assessed and approved. The plans are also to be suitable for use during construction, installation, hydrotesting, survey and maintenance of the riser system.

2.1.2 In general, engineering drawings and documents should be submitted electronically.

2.2 Specifications

2.2.1 Adequate design specifications, appropriate in detail to the approval required, are to be submitted for information.

2.2.2 Specifications for the design, construction and fabrication of the riser system, structure and associated equipment are to be submitted. The specifications are to include details of materials, grades/standards, consumables, construction and installation procedures and modes of operation with applicable design criteria. The specifications are also to include the proposed design codes.

2.2.3 Specifications and documentation are to be submitted, covering all instrumentation and monitoring systems proposed to cover the fabrication, installation and operating phases of risers, fittings and equipment.

2.3 Plans and data to be submitted

2.3.1 Plans and data covering the following items are to be submitted for approval, as relevant:

- Bend stiffeners.
- Bend stiffeners latching mechanisms.
- Bend restrictors.
- Buoyancy arches and fittings.
- Buoyancy modules.
- Construction and laying procedures.
- Corrosion protection system.
- Curvature bending stiffeners.
- Details of all attachments.
- Details of riser system control and communications.
- Details of sea bed.
- Emergency shut-down system and other safety devices, including pressure transient (surge) relief.
- End fittings.
- Instrumentation and communication line diagrams.
- Layout of risers and associated platform arrangements, including protection of risers.
- Leak detection system and hardware.
- Location survey showing name, latitude and longitude of terminal locations, location of isolating valves, position of platforms or other fabrications, shipping channels, presence of cables, pipelines and wellheads, etc.
- Mid water arches
- Quality Control and NDE procedures.
- Riser dimensions.
- Riser material specifications, including appropriate test results.
- Riser support details.
- Riser wall thickness tolerances.
- Sizes and details of expansion loops, reducers, etc.
- Test schedules for communication systems, controls, emergency shut-down systems and other safety devices, which are to include the methods of testing and test facilities provided.
- Tether arrangements
- Type and thickness of corrosion coating.
- Type and details of all pig traps, valves and control equipment, etc.
- Welding specification, details and procedures.

2.3.2 The following supporting plans and documents are to be submitted:

- Reference plans and listing of standard components, e.g., tees, reducers, connectors, valves, elbows, etc.
- Reference plans of anodes, sleeves, etc.

2.4 Calculations and data

2.4.1 The following is to be submitted where relevant to the riser system:

- Analyses of riser system behaviour including: strength, buckling, vortex shedding, on-bottom stability, displacements, vibration, fatigue, fracture and buckle propagation and minimum bend radii.
- Buoyancy and stability data for all risers.
- Burst pressure of flexible risers.
- Calculations and documentation of all design loads covering: manufacture, installation and operation.
- Corrosive nature of line contents.
- Corrosive nature of sea-water and sea bed soils.
- Current, tidal current and storm surge velocities and directions.
- Design cathodic protection potential.
- Damaging tension of flexible risers.
- Design life.
- Design pressure and temperature.
- Design throughput.
- Fluid to be conveyed. (The maximum partial pressure and dew point of H_2S, $C0_2$ and H_20 for gas risers).
- Ice conditions, which may affect riser system.
- Leak detection accuracy and response.
- Maximum and minimum operating temperatures including distributions along the riser.
- Maximum and minimum temperatures of water and air.
- Maximum operating pressure.
- Maximum Excursion Envelopes (MEEs) for riser system (in the x, y and z axes) to prevent damage. MEEs to be provided in the operational and survival conditions, with the mooring system in connected and disconnected (where appropriate) conditions.
- Marine growth density and thickness profiles (varying with water depth) plotted against time, over the field life.
- Product density.
- Sea bed geology and soil characteristics including stability and sand waves, etc.
- Sea bed topography and bathymetry in way of riser system and any possible deviation or future development.
- Seismic activity survey.
- Test pressure to be applied.
- Type, activity and magnitude of marine growth predicted.
- Wave heights, periods and directions.
- Wind velocities and directions.

2.5 Operations Manual

2.5.1 The allowable modes of operation including the maximum and minimum internal pressure, product temperature and flow rate together with the operating and maximum environmental criteria on which classification is based are to be stated in the unit's Operations Manual, as required by Ch 1,3.

2.5.2 The Manual is to contain instructions and guidance on any actions which need to be taken to satisfy environmental considerations and the safe operation of the riser system.

■ *Section 3* Materials

3.1 General

3.1.1 The type and grade of materials chosen for the risers, valves and associated equipment are to be in accordance with the Rules for Materials or a recognised National or International Standard. In cases when a specification is not covered by LR's Rules, full details of the material specification, testing documentation and all properties are to be submitted for approval.

3.1.2 Materials are to be selected in accordance with the requirements of the design in respect of carriage of the product, strength, fatigue, fracture resistance and corrosion resistance.

3.1.3 Due consideration is to be given to temperature and other environmental conditions on the performance of the material, including toughness at the minimum operating temperature, the effects of corrosion, and other forms of deterioration both in service and whilst being stored or handled.

3.1.4 Riser material for H_2S-contaminated products (sour service) is to comply with the NACE MR0175/ISO15156 - *Petroleum and Natural Gas Industries – Materials for use in H_2S-containing Environments in Oil and Gas Production, see* Appendix A.

3.1.5 Steel grades for operation in areas where the design air temperature is below minus 20°C and in severe ice conditions (e.g., arctic waters), will be specially considered.

3.1.6 An approved system of corrosion control is to be fitted, where appropriate. Full details are to be submitted, *see* Pt 8, Ch 1.

■ *Section 4* Environmental considerations

4.1 General

4.1.1 The Owner or designer is to specify the environmental criteria for which the riser system is to be approved. The extreme environmental conditions applicable to the location are to be defined, together with all relevant operating environmental limits. Full particulars are to be submitted with sufficient supporting information to demonstrate the validity of the environmental parameters.

4.1.2 The extreme environmental criteria to be taken into account in the riser system design are, in general, to be based on a return period of 50 years, *see also* Pt 4, Ch 3,4.

4.2 Environmental factors

4.2.1 The following environmental factors are to be considered in the design of the riser system:

- Air and sea temperatures.
- Current.
- Fouling.
- Ice.
- Water depth.
- Wave.
- Wind.

4.2.2 Environmental factors to be accounted for in the design loadings are contained in Pt 4, Ch 3,4 together with the additional considerations below.

4.3 Waves

4.3.1 When using acceptable wave theories to determine local wave velocities for smooth cylindrical members, appropriate hydrodynamic coefficients should be used. These values should be modified to account for marine growth, for proximity to the sea bed, or structural members on the unit.

4.4 Current

4.4.1 Where a current acts simultaneously with waves, the effect of the current is to be included. The current velocity is to be added vectorially to the wave particle velocity. The resultant velocity is to be used to compute the total force.

4.4.2 In the absence of more detailed information, the distribution of current velocity with depth may be assumed to vary according to the 1/7th power law.

4.5 Vortex shedding

4.5.1 Consideration is to be given to the possibility of vibration of structural members due to von Karman vortex shedding. (This is to apply to wind on exposed risers, and to wave and current on immersed risers).

4.6 Ice

4.6.1 Riser systems intended for operation in ice are to be designed to minimise the effect of ice loading. Proposals are to be submitted for consideration.

Section 5
Design loadings

5.1 General

5.1.1 All modes of operation are to be investigated using realistic loading conditions, including buoyancy, unit motions and gravity loadings and operational loads (temperature, pressure, etc.) together with relevant environmental loadings due to the effects of wind, waves, currents, vibrations, ice, and where necessary, the effects of earthquake, sea bed supporting capabilities and friction, temperature, fouling, etc.

5.1.2 The design of the riser system is to take account of all loads which can be imposed during its service life.

5.1.3 The design is also to take account of loads related to the construction, transportation and site installation stages.

5.2 Dead loads

5.2.1 All gravity loadings are to be taken into account and should include self-weight of the riser system and attachments. The deadweight of contents is to be included.

5.2.2 Buoyancy of risers including attached equipment is to be taken into account.

5.2.3 Constraints and loads arising from supports and attachments should be taken into account. Also any scour or subsidence of sea bed should be assessed.

5.3 Live loads

5.3.1 Static pressure, pressure surge transients and any peak 'hammer-blow' effects are all to be considered, together with corresponding temperatures.

5.3.2 Dynamic inertial vibrations and flutter induced by any activation, including vortex shedding, are to be considered.

5.4 Environmental loads and motions

5.4.1 The environmental loading on a riser system and its motion responses are to be determined for at least the design environmental conditions given in Section 6. Dynamic effects are to be considered.

5.4.2 The loads and motions can be established by model testing or by suitable calculations or both. The possibility of resonant motion is to be fully investigated.

5.4.3 Account is to be taken of the effect of marine growth. Both increase in the dimensions and the change in surface characteristics are to be considered.

5.4.4 Where model testing is to be adopted:

(a) the test programme and the model test facilities are to be to LR's satisfaction;

(b) the relative directions of wind, wave and current are to be varied as required to ensure that the most critical loadings and motions are determined;

(c) the tests are to be of sufficient duration to establish low frequency motion behaviour; and

(d) the model testing is required to give suitable data pertaining to both strength and fatigue design aspects of the riser system.

5.5 Other loadings

5.5.1 Loads imposed during site installation, including those due to motion of the laying ship/unit, are to be assessed and taken into account. The curvature taken up during laying and loads imposed thereby are to be assessed and arrangements made for laying procedures to avoid any damage or overstress.

5.5.2 Hydrostatic effects are to be included in the design. Hydrostatic loading can be taken as the difference between internal and external pressures, as appropriate.

5.5.3 The riser system design should also take account of accidental loading, where relevant, and required test loads, *see* Section 9.

5.5.4 The riser system is to be designed to withstand the most unfavourable combinations of pressure, temperature and environmental loadings under normal operating conditions combined with the effects of the most severe single fault that might arise in the positioning system.

5.5.5 Scouring effects are to be considered for the support conditions of steel flexible risers at the touchdown locations.

Section 6
Strength

6.1 General

6.1.1 This Section defines the strength requirements, including static and dynamic aspects, for welded steel riser systems, flexible riser systems and hoses.

6.1.2 The design is to be analysed in accordance with acceptable methods and procedures and the resultant stresses or factors of safety determined.

6.1.3 In general, the strength of the riser system is to be determined from a three-dimensional analysis. Only if it can be demonstrated that other methods are adequate will they be considered.

6.1.4 The riser system is to be designed such that under transient operating conditions the maximum allowable operating pressure may not be exceeded by more than 10 per cent.

6.2 Structural analysis

6.2.1 The loading combinations considered are to represent all modes of operation so that the critical design cases are established.

6.2.2 All loads applicable to the design, as defined in Section 5, are to be fully covered in the loading combinations.

6.2.3 A fully representative number of design cases are to be defined, each of which should be associated with appropriate environmental conditions and allowable yield ratios or factors of safety. The design cases are to cover all critical aspects of riser system installation, testing and operation.

6.2.4 A detailed analysis of the riser system, including interaction with pipeline and expansion loop is to be carried out. This is to take account of thermal, hydrodynamic, gravity, buoyancy and pressure effects and vessel motions. Modelling is to describe riser geometry and stiffness, and soil interaction, including loss of contact.

6.2.5 Riser supports and stiffener bend restrictor forces are to be determined, and strength checks carried out.

6.3 Flexible risers and hoses

6.3.1 The design of flexible risers and associated appurtenances and fittings is to be based on sound engineering principles and practice, and is to be in accordance with recognised National or International Standards or Codes of Practice. Design calculations are to be submitted and, where considered necessary, LR will carry out independent analysis of the strength and stability of the flexible risers, *see* Appendix A, A1.2.10.

6.3.2 For all critical loading combinations relevant to the design axial loading, internal/external pressure and radius of curvature are to be considered in a rational manner.

6.3.3 Other factors which adversely affect the integrity of the riser such as abrasion, ageing, corrosion, fatigue and fire are also to be considered.

6.3.4 For fatigue *see* 6.4.6; however, endurance curves should also account for fluid permeation through polymers and potential accidental ingress of sea-water resulting from damage to the external sheath.

6.3.5 Special attention is to be given to riser end fittings to ensure effective bonding, pressure containment and load transfer.

6.3.6 In general, riser displacements are to achieve acceptable clearances with adjacent risers, mooring lines, unit structures and the sea bed. However, in extreme cases interference may be allowed, *see* 1.5.3.

6.3.7 Critical design parameters are to be demonstrated by means of appropriate tests and calculations.

6.4 Welded steel risers

6.4.1 The design of steel risers and associated appurtenances and fittings is to be based on sound engineering principles and practice, and is to be in accordance with recognised National or International Standards or Codes of Practice. Design calculations are to be submitted and, where considered necessary, LR will carry out independent analysis of the strength and stability of the steel risers, *see* Appendix A, A1.2.10.

6.4.2 **Yielding**: For any particular location, two stress intensity calculations will be required, as follows:

(a) Hoop stress calculations are to be made utilising the minimum specification wall thickness less corrosion allowance, as appropriate.
(b) All axial stresses arising from end load, bending moment, shear and torsion are to be combined with hoop stress to give an equivalent stress based on the Mises-Hencky criterion to conform with specified yield ratio limits. For this purpose, nominal section dimensions may be used.

6.4.3 **Vortex shedding response**:

(a) The effects of vortex-induced oscillations are to be accounted for. The effect of axial forces on natural frequency is to be included.
(b) The restraining effect of external spans, and relief due to wave and current directionality may be included provided that sufficient environmental data is available.
(c) In all cases, the effect of vortex shedding on fatigue life is to be checked.

6.4.4 **Buckling**. Local and overall buckling of the riser is to be checked for all locations and loading conditions for which free spans may arise. The worst combinations of axial and lateral loading are to be considered.

6.4.5 **Stress concentrations**. The effect of notches, stress raisers and local stress concentrations is to be taken into account in the design of the load-carrying elements.

6.4.6 **Fatigue**:

(a) Fatigue damage due to cyclic loading is to be considered in the design of the riser. The cyclic loading due to internal (contents) pressure fluctuations and external environmental loadings is to be taken into account. The extent of the fatigue analysis will be dependent on the mode and area of operations.

(b) Fatigue design calculations are to be carried out in accordance with the analysis procedures and general principles given in Pt 4, Ch 5,5, or other acceptable method, and the fatigue life calculations are to be based on the relevant stress range/endurance curves applicable to the service environment incorporating appropriate stress concentration factors .

(c) The minimum factors of safety on fatigue life are not to be less than as required by Pt 4, Ch 5.5.6.

6.4.7 **Plastic analysis**. Where plastic design methods are to be employed, the load factors will be specially considered.

6.5 Pig trap

6.5.1 Pig traps are to be designed to the requirements of a recognised pressure vessel code and since they are considered as part of the riser and associated equipment the hoop stress is not to exceed 60 per cent of the minimum yield stress of the material.

6.6 Riser supports and attachments

6.6.1 The riser supports and other attachments are to be designed to meet suitable structural design codes. Where the supports are attached to the structure of the unit the permissible stresses in the structure are to comply with Pt 4, Ch 5,2.

6.7 Mechanical items

6.7.1 The design of components such as valves and similar apparatus is to be in accordance with an acceptable design method or recognised Code or Standard.

■ *Section 7* Welding and fabrication

7.1 General

7.1.1 Welding, weld procedures and approval of welders are to be in accordance with the general requirements of Pt 4, Ch 8. When agreed with LR, the fabrication of riser systems may be in accordance with a recognised Code or Standard, *see* Appendix A.

7.1.2 The proposals for NDE procedures are to be agreed with LR prior to the commencement of construction.

7.1.3 All butt welds are to be subjected to 100 per cent NDE. Examination by radiography is to be to a Standard acceptable to LR, e.g., BS 2910: *Methods for Radiographic Examination of Fusion Welded Circumferential Butt Joints in Steel Pipes,* with acceptance criteria as detailed in the Construction Code, or BS 4515: *Specification for Process of Welding of Steel Pipelines on Land and Offshore*, if not specified in the Code. Proposals for examination by ultrasonics are to be submitted for review and acceptance.

7.1.4 All defective sections of welds are to be cut out, carefully re-welded and re-examined.

7.1.5 Weld procedures for repairs and alterations are to be qualified and approved by LR.

■ *Section 8* Installation

8.1 General

8.1.1 Specifications covering the site installation procedures are to be submitted for approval.

8.2 Location Survey

8.2.1 Specifications, plans and data are to comply with 2.3.1. Additional data is to be submitted specifying sea bed preparation, extent and means of execution and survey prior to installation.

8.2.2 The construction specification is to specify the tolerance within which the riser system is to be positioned.

8.3 Installation procedures

8.3.1 The equipment used for operations is to be agreed by LR for the processes specified.

8.3.2 Individual risers, equipment, fittings and sub-assemblies are to be handled and stored with care, especially components with anodes or heavy anode bracelets. No components are to be stored in a manner which will cause damage or deformation.

8.3.3 All components and sub-assemblies are to be inspected before installation and be approved to the satisfaction of the Surveyor.

8.3.4 The installation of the riser is not to introduce any unscheduled loading and the transfer of loading to riser supports is to be shown to be in accordance with design specifications.

8.3.5 All monitoring systems are to be operated and calibrated to the Surveyor's satisfaction during all laying and installation operations.

8.4 Completion Survey

8.4.1 As soon as is practicable following installation and prior to start-up, a survey of the entire riser system is to be carried out.

■ *Section 9*
Testing

9.1 Hydrostatic testing

9.1.1 The requirements of 1.10, 1.11 and 1.12 regarding certification and testing are to be complied with.

9.1.2 **Steel risers**:

(a) The riser system is to be hydrostatically tested after installation. Hydrostatic Testing Procedures are to comply with recognised international Codes and Standards.
(b) A written procedure is to be developed before hydrostatic testing commences. The acceptance criteria are to be agreed by LR.

9.1.3 **Flexible risers**. For flexible risers, pressure testing includes acceptance tests in the factory and hydrostatic test after installation. The acceptance test pressure should be in accordance with international Codes and Standards for flexible risers.

9.1.4 It is permissible to have pressure variations during a hydrostatic test provided they can be explained in terms of temperature changes and/or motions of the riser system.

9.1.5 In order to calculate the effect of temperature on pressure, it is essential that the temperature of the fluid in the pipe is measured and recorded at the same time as each pressure measurement is made and recorded. Ambient air or sea-water temperature are not relevant.

9.1.6 As a minimum, the temperature is to be measured near each end of the riser. Preferably at least one transducer on the sea bed part of the riser should also be provided.

9.1.7 Temperature sensors attached to the outside of the steel wall of a riser and insulated from the thermal effects of the sea are acceptable provided the test medium has been in the riser for at least 24 hours before the test is started, in order to allow the temperature of the fluid and steel to stabilise.

9.1.8 When conducting a hydrostatic test of a riser, the following requirements are to be complied with:

(a) The pressure (and temperature, if applicable) is to be continuously recorded for the duration of the test on a chart recorder.
(b) The chart is to be signed by the Surveyor at the beginning and end of the test.
(c) Pressure (and temperature, if applicable) readings are to be made at intervals not greater than 30 minutes and tabulated.
(d) Where temperature readings are to be taken the line is to be filled at least 24 hours before the test to enable the temperature to stabilise.
(e) The results of a hydrostatic test are to be recorded by a dossier containing the following:
    - Copies of all charts made during the test.
    - Copies of all tables of pressure readings (and temperature readings where applicable) made during the test.
    - Copies of calibration certificates for the pressure recorders used.
    - Calculations demonstrating temperature correction to pressure change where applicable.

9.1.9 The sections of riser are to be hydrostatically tested at the place of manufacture in accordance with Chapter 6 of the Rules for Materials or the relevant National Standard.

9.1.10 Before a consent to start-up a riser can be given, evidence of a satisfactory hydrostatic test is to be provided. The evidence is to relate to a test completed during the 12 months prior to the date of application for the consent to start up.

9.2 Buckle detection

9.2.1 An adequate examination is to be carried out to determine that the completed riser is free from buckles, dents or similar damage.

9.3 Testing of communications, controls and safety systems

9.3.1 Communication systems, remote and automatic controls, emergency shut-down systems and other safety devices are to be tested in accordance with the approved test schedules required by 2.3.1.

■ *Section 10*
Operation and repairs

10.1 Operation procedures

10.1.1 A written operation procedure is to be prepared and issued prior to the riser system being put into operation. One operation procedure may, where applicable, cover several riser systems of the same type.

10.1.2 Where a riser system forms part of a system covering other lines, platforms, terminals, etc., the operating procedure is to embrace those parts of the entire system which are relevant to the operation of the riser system.

10.1.3 In order to minimise the risk of damage to the riser system, it is the Owner's/Operator's responsibility to ensure that supply boat approach routes to the installation are strictly controlled. A mooring procedure is to be produced which clearly indicates safe and hazardous anchoring areas.

10.1.4 Operation procedures are to be written in English with translations into other languages, as necessary, for the operating personnel involved.

10.2 Repairs

10.2.1 It is the Owner's responsibility to inform LR of any defects found. The exact location, nature and extent of the defects are to be stated. The requirements of 1.13 are to be complied with.

10.2.2 Plans and particulars of any proposed repairs are to be submitted for approval. All repair work is to be carried out to the satisfaction of LR's Surveyors.

Wind Turbine Installation and Maintenance Vessels and Liftboats

Section

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter apply to units or vessels engaged in installation and/or maintenance activities relating to offshore wind turbines and cover the unit types indicated in 1.2.

1.1.2 The requirements of this Chapter also apply to liftboats whose primary function is to provide support services to offshore wind turbine installations or other types of offshore installation, *see* 1.2.

1.1.3 The requirements in this Chapter are supplementary to those given in the relevant Parts of the Rules.

1.1.4 Surface type units and surface type self-elevating units are to comply with LR's *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships), but aspects which relate to the specialised offshore function of the unit will also be considered on the basis of these Rules.

1.1.5 Requirements additional to these Rules may be imposed by the National Authority with whom the unit is registered and/or by the Administration within whose territorial jurisdiction the unit is operating.

1.2 General definitions

1.2.1 A **column-stabilised unit** is a unit with a working platform supported on widely spaced buoyant columns. The columns are normally attached to buoyant lower hulls or pontoons. These units are normally floating types but can be designed to rest on the sea bed.

1.2.2 A **liftboat** is a unit with a buoyant hull (generally either triangular or pontoon shaped) with moveable legs capable of raising the hull above the surface of the sea and designed to operate as a sea bed-stabilised unit in an elevated mode. The legs may be designed to penetrate the sea bed, or be attached to a mat or individual footings which rest on the sea bed. In general, installation and maintenance activities would be undertaken in the jacked-up condition. These unit types are generally self-propelled.

1.2.3 A **self-elevating (or jack-up) unit** is a floating unit which is designed to operate as a sea bed-stabilised unit in an elevated mode. These units have a buoyant hull (generally either triangular or pontoon shaped) with movable legs capable of raising its hull above the surface of the sea. The legs may be designed to penetrate the sea bed, or be attached to a mat or individual footings which rest on the sea bed. These unit types are generally not fitted with a propulsion system.

1.2.4 A **surface type floating unit** is a unit with a ship or barge type displacement hull of single or multiple hull construction intended for operation in the floating condition.

1.2.5 A **surface type self-elevating (or jack-up) unit** is a floating unit, which is designed to operate as a sea bed-stabilised unit in an elevated mode. These units have a ship type displacement hull of single or multiple hull construction fitted with moveable legs capable of raising the hull above the surface of the sea. The legs may be designed to penetrate the sea bed, or be attached to a mat or individual footings which rest on the sea bed. In general, installation and maintenance activities would be undertaken in the jacked-up condition. These unit types are generally self-propelled.

1.2.6 Further general definitions for all unit types can be found in Pt 1, Ch 2,2.

1.3 Guidance note

1.3.1 Summary information for unit types engaged in installation and/or maintenance activities relating to offshore wind turbines can be found in LR's Guidance Note *Mobile Offshore Units – Wind Turbine Installation Vessels*.

1.3.2 Summary information for Liftboats engaged in support services to offshore wind turbine installation or other types of offshore installation can be found in LR's Guidance Note *Mobile Offshore Units – Liftboats*.

1.3.3 The Guidance Notes referred to in 1.3.1 and 1.3.2 provide summary information on the following topics:

- Classification Rules, Regulations and procedures.
- National Administration requirements.
- Documentation.
- Applicable LR Rule requirements for unit types identified in 1.2.

1.3.4 For the unit types identified in 1.2.1, 1.2.3, 1.2.4 and 1.2.5, Appendices A2, A3, A4 and A5 of the Guidance Note referred to in 1.3.1 include summary Tables indicating the relevant Parts and Chapters of these Rules and the Rules for Ships, which are to be applied to the individual unit types.

1.3.5 For the unit type identified in 1.2.2, the Guidance Note referred to in 1.3.2 includes summary Tables indicating the relevant Parts and Chapters of these Rules and the Rules for Ships, which are to be applied to the individual unit types.

1.4 Class notations

1.4.1 The Regulations for classification and the assignment of class notations are given in Pt 1, Ch 2, to which reference should be made.

1.4.2 In general, units or vessels engaged in installation and/or maintenance activities relating to offshore wind turbines, which comply with the requirements of this Chapter and the relevant Parts of the Rules will be eligible for the assignment of the following class type notations:
- **MainWIND**

1.4.3 In general, liftboats whose primary function is to provide support services to offshore wind turbine installations or other types of offshore installation which comply with the requirements of this Chapter and the relevant Parts of the Rules will be eligible for the assignment of the following class type notations:
- **Liftboat**

1.4.4 Units engaged in more than one function may be assigned a combination of class type notations at the discretion of the Classification Committee.

1.4.5 Lifting appliances are to comply with LR's *Code for Lifting Appliances in a Marine Environment* (LAME), *see also* Chapter 11.

1.4.6 Where the lifting appliances form an essential feature of a classed unit, the special feature class notation '**LA**' will be assigned, *see* Chapter 11.

1.4.7 Other special features class notations associated with lifting appliances may be assigned, *see* Chapter 11.

1.4.8 Where the lifting appliance is not assigned a special feature class notation, the crane is to be certified by a recognised competent body, *see* Ch 1, 1.2 of LR's LAME.

1.5 Scope

1.5.1 The following additional topics applicable to the class type notation are covered by this Chapter:
- Hull scantlings
- Strength of structure for accommodation.
- Supports for containerised modules.
- Structure in way of cranes.
- Structure below any other major mission equipment, laydown areas, etc.
- Positional mooring.
- Main and auxiliary machinery.
- Control and electrical engineering.
- Safety systems, hazardous areas and fire.
- Corrosion control.

1.6 Installation layout and safety

1.6.1 Living quarters, lifeboats and other evacuation equipment are to be located in non-hazardous areas.

1.6.2 The requirements for fire safety are to be in accordance with the requirements of a National Administration, *see* Pt 1, Ch 2,1 and Pt 7, Ch 3.

1.6.3 Additional requirements for hazardous areas, safety and communication systems are given in Part 7 and are to be applied to the relevant unit type. For surface type self-elevating units, the requirements for surface type units are to be complied with as applicable.

1.7 Survey

1.7.1 For all unit types, the requirements for periodical surveys are defined in Pt 1, Ch 2,3 and Ch 3.

1.7.2 In general, where a classed or certified lifting appliance is fitted to a classed unit, the survey requirements of the lifting appliance are to be in accordance with Chapter 9 of LR's LAME and Part E, Ch 8 of LR's *Marine Survey Procedures Manual*.

1.8 Plans and data submission

1.8.1 Plans, calculations and data are to be submitted as required by the relevant Parts of the Rules, together with the additional plans and information listed in this Chapter.

1.8.2 For units or vessels engaged in installation and/or maintenance activities relating to offshore wind turbines, *see also* Ch 2,8 of LR's Guidance Note *Mobile Offshore Units – Wind Turbine Installation Vessels*, for additional information on the plans and data to be submitted.

1.8.3 For liftboats engaged in support services to offshore wind turbine installation, *see also* LR's Guidance Note *Mobile Offshore Units – Liftboats*, for additional information on the plans and data to be submitted.

■ *Section 2* Structure

2.1 Plans and data submission

2.1.1 In addition to the structural plans and information as required by Ch 2,8 of LR's Guidance Note *Mobile Offshore Units – Wind Turbine Installation Vessels* and also LR's Guidance Note *Mobile Offshore Units – Liftboats*, the following additional plans and information are to be submitted as applicable:

- General arrangement plans.
- Structural plans of the accommodation including deck houses and modules.
- Design calculations for containerised modules (if applicable).
- Structural arrangements in way of crane supports and boom rests (if applicable).
- Structural arrangements in way of permanently attached, purpose built cargo stacking and securing arrangements.
- Structural arrangements under the weather deck which support heavy items of deck cargo such as nacelles, towers, blades, foundations and temporary transportation frames.
- Structural arrangements and supports under any other major mission or topsides equipment.
- Positional mooring equipment and supporting structures (if applicable).

2.2 General

2.2.1 The hull strength is to take into account the applied weights and forces due to the accommodation, deck cargo, cranes and, if applicable, mooring forces and the local structure is to be suitably reinforced. Appendices A2, A3, A4 and A5 of the Guidance Note referred to in 1.3.1 include summary Tables indicating the relevant Parts and Chapters of these Rules and the Rules for Ships, which are to be applied to the individual unit types for hull strength requirements.

2.2.2 For the unit types identified in 1.2.1, 1.2.3, 1.2.4 and 1.2.5, the hull scantlings for each unit type are to be calculated in accordance with the relevant parts of the Rules identified in Appendices A2, A3, A4 and A5 of the Guidance Note *Mobile Offshore Units – Wind Turbine Installation Vessels*.

2.2.3 For the unit type identified in 1.2.2, the hull scantlings for each unit type are to be calculated in accordance with the relevant parts of the Rules identified in the Guidance Note *Mobile Offshore Units – Liftboats*.

2.2.4 The design loadings for all purpose built cargo stacking arrangements, support frames and trusses are to be defined by the designers/Builders and calculations are to be submitted in accordance with an internationally recognised Code or Standard as defined in Appendix A. The supporting structure and attachments below the purpose built cargo stacking arrangements, support frames and trusses are to be designed for all operating conditions and for the emergency condition as defined in Ch 8,1.4. For a surface type self-elevating unit in the afloat condition, the angle of inclination in the emergency static condition is to be considered in accordance with the requirements for a self-elevating unit.

2.2.5 The supporting structure and attachments below any other mission equipment items are to be designed for all operating conditions and for the emergency condition as defined in Ch 8,1.4. For a surface type self-elevating unit in the afloat condition, the angle of inclination in the emergency static condition is to be considered in accordance with the requirements for a self-elevating unit.

2.2.6 When the unit is intended to operate in an area which could result in the build-up of ice on the crane, leg and any other structure, the effects of ice loading are to be included in the calculations. *See* Pt 4, Ch 3,4.

2.2.7 For column-stabilised and self-elevating units, the decks and other under-deck structure supporting the mission equipment and deck cargo are to be suitable for the local loads at the mission equipment and deck cargo support points and an agreed uniformly distributed load acting on the deck. *See* Pt 4, Ch 6,2.

2.2.8 For surface type and surface type self-elevating units, the decks and other under-deck structure supporting the mission equipment and deck cargo are to be suitable for the local loads at the mission equipment and deck cargo support points and an agreed uniformly distributed load acting on the deck. *See* Pt 3, Ch 3,5 of the Rules for Ships.

2.2.9 In general, all seatings, platform decks, girders and pillars supporting mission equipment and deck cargo are to be arranged to align with the main hull structure, which is to be suitably reinforced, where necessary, to carry the appropriate loads.

2.2.10 Attention should be paid to the capability of support structures to withstand buckling. For column-stabilised and self-elevating units, *see* Pt 4, Ch 5,4. Surface type and surface type self-elevating units are to comply with Pt 3, Ch 4,7 of the Rules for Ships, but aspects which relate to the specialised offshore function of the unit will be considered on the basis of Pt 4, Ch 5,4.

2.2.11 Crane pedestals are classification items and are to comply with the requirements of Chapter 11.

2.2.12 For liftboats, a fatigue life assessment of all relevant structural elements in accordance with Pt 4, Ch 5,5 is required. Structural elements to be assessed include lattice legs and connections to mats and footings and leg support structure. The fatigue loading spectrum may be based on the transit environmental criteria.

2.2.13 The minimum fatigue life of a liftboat is to be specified by the Owners, but is generally not to be less than 20 years, unless agreed otherwise with LR.

2.2.14 For liftboats, when considering the overturning moment, in no case is the variable load to be taken greater than 10 per cent of the maximum variable load. The percentage of variable load used when considering the overturning moment is to be stated in the Operations Manual.

2.2.15 For liftboats, when calculating the overturning moment, the unit should be considered supported through the centre line of the legs about which the unit is considered rotating. However, for hard foundation bases, the maximum stressed edge of the mat may be taken as an appropriate support position. In this instance, a safety factor of at least 1,2 against overturning is considered acceptable.

2.2.16 For liftboats, the Owner is to specify the minimum design environmental criteria and return periods for which the unit is to be approved. In general, a return period of not less than 1 year should be used for operational conditions and 100 years for survival conditions.

2.2.17 For liftboats, restricted to seasonal operations in order to avoid extremes of wind and wave, such seasonal limitations must be specified. The unit's actual minimum design environmental criteria and return periods used in the design of the liftboat are to be stated in the Operations Manual.

2.2.18 The thickness of marine growth to be taken into account during the design of submerged members on lift boats is not to be less than 50 mm. The actual thickness of marine growth used in the design of the liftboat is to be stated in the Operations Manual and the design limit is not to be exceeded in service.

2.2.19 For liftboats, the minimum design deck loads are to be specified by the Owner and are not to be less than the minimum design deck loads required by Pt 4, Ch 6,2.

2.2.20 For liftboats, the foundation fixity need not be considered for the in-place strength analysis.

2.3 Deckhouses and modules

2.3.1 For column-stabilised and self-elevating units, the scantlings of structural deckhouses are to comply with Pt 4, Ch 6,9. Where deck-houses support equipment loads, they are to be suitably reinforced.

2.3.2 For surface type and surface type self-elevating units, the scantlings of structural deckhouses are to comply with Pt 3, Ch 8,2 of the Rules for Ships. Where deck-houses support equipment loads, they are to be suitably reinforced.

2.3.3 The strength of containerised modules which do not form part of the main hull structure will be specially considered in association with the design loadings.

2.3.4 When containerised modules can be subjected to wave loading or protect openings leading into buoyant spaces, the scantlings are not to be less than required by 2.3.1 or 2.3.2, as applicable.

2.3.5 For column-stabilised and self-elevating units, the structural strength of the connections between containerised modules and the supporting frame or structure are to comply with the general strength requirements of Pt 4, Ch 6,9, taking into account the unit's motions and marine environmental aspects. For surface type and surface type self-elevating units, the scantlings of structural deckhouses are to comply with Pt 3, Ch 8,2 of the Rules for Ships.

2.3.6 The connections of containerised modules are also to satisfy an emergency static condition with an applied horizontal force F_H in any direction as follows:

$F_H = W \sin\theta$ N (tonne-f)

where

θ = 25° for semi-submersible and surface type units

θ = 17° for self-elevating and surface type self-elevating units

W = weight of the modules supported in N (tonne-f).

2.3.7 In the emergency static condition, defined in 2.3.6, the permissible stress levels are to be in accordance with Pt 4, Ch 5, 2.1.1(c).

2.4 Permissible stresses

2.4.1 In general, for column-stabilised and self-elevating units the permissible stresses in the structure in operating, transit and survival conditions are to comply with Pt 4, Ch 5,2, but the minimum scantlings of the local structure are to comply with Pt 4, Ch 6.

2.4.2 In general, for surface type and surface type self-elevating units the primary hull strength and the minimum scantling requirements for the local structure can be considered under Pt 3, Ch 4 and Pt 4, Ch 1 of the Rules for Ships. However, aspects which relate to the specialised offshore function of the unit will be considered under the basis of Pt 4, Ch 5,2.

2.4.3 Permissible stresses for lattice type structures may be determined from an acceptable code, *see* Appendix A.

2.5 Watertight and weathertight integrity

2.5.1 For column-stabilised and self-elevating units, the general requirements for watertight and weathertight integrity are to be in accordance with Pt 4, Ch 7.

2.5.2 For surface type and surface type self-elevating units, the general requirements for watertight and weathertight integrity are to be in accordance with Pt 3, Ch 11 and Ch 12 of the Rules for Ships.

2.5.3 The integrity of the weather deck is to be maintained. Where mission equipment penetrates the weather deck and is intended to constitute the structural barrier to prevent the ingress of water to spaces below the deck, its structural strength is to be equivalent to the Rule requirements for this purpose. Otherwise, such items are to be enclosed in superstructures or deck-houses fully complying with the Rules. Full details are to be submitted for approval.

2.5.4 Where items of mission equipment penetrate watertight boundaries, the watertight integrity is to be maintained and full details are to be submitted for approval.

2.6 Materials

2.6.1 For column-stabilised and self-elevating units, the general requirements for materials are to be in accordance with Pt 3, Ch 1,4 and Pt 4, Ch 2.

2.6.2 For surface type and surface type self-elevating units, the general requirements for materials are to be in accordance with Pt 3, Ch 2 and Pt 4, Ch 1,2 of the Rules for Ships. Aspects which relate to the specialised offshore function of the unit will be considered under the basis of Pt 3, Ch 1,4 and Pt 4, Ch 2.

■ *Section 3* Positional mooring systems

3.1 Application

3.1.1 The requirements of this Section apply to units which are intended to perform their primary designed service function only while they are moored with a catenary type positional mooring system including thruster-assisted systems.

3.1.2 The mooring system will be considered for classification on the basis of operating constraints and procedures specified by the Owner and recorded in the Operations Manual.

3.1.3 The mooring system is to comply with the requirements of Chapter 10.

3.1.4 For column-stabilised and self-elevating units, dynamic positioning systems are to comply with the requirements of Chapter 9. For surface type and surface type self-elevating units, dynamic positioning systems are to comply with the requirements of Pt 7, Ch 4 of the Rules for Ships.

3.1.5 The support structure in way of fairleads and winches, etc., are to be in accordance with Pt 4, Ch 6,1.

■ *Section 4* Main and auxiliary machinery

4.1 Application

4.1.1 For surface type units, the general requirements for main and auxiliary machinery are to be in accordance with Pt 5, Ch 1 of the Rules for Ships. Aspects which relate to the specialised offshore function of the unit will be considered on the basis of Pt 5, Ch 1 and are to be complied with as applicable. All other main and auxiliary machinery requirements are to be in accordance with Pt 5, Ch 2 to Ch 22 of the Rules for Ships and are to be complied with as applicable.

4.1.2 For surface type self-elevating units, the general requirements for main and auxiliary machinery are to be in accordance with Pt 5, Ch 1 of the Rules for Ships. Aspects which relate to the specialised offshore function of the unit will be considered on the basis of Pt 5, Ch 1 and Ch 4,2, and are to be complied with as applicable. All other main and auxiliary machinery requirements are to be in accordance with Pt 5, Ch 2 to Ch 22 of the Rules for Ships and are to be complied with as applicable.

4.1.3 For both column-stabilised and self-elevating units, the main and auxiliary machinery requirements are to be in accordance with Part 5 and are to be complied with as applicable.

4.1.4 For all unit types, due account should be taken of the unit type and operational role when applying these requirements.

4.2 Angle of inclination

4.2.1 For surface type units, the angles of inclination are to be in accordance with Table 1.3.2 in Pt 5, Ch 1,3.7 of the Rules for Ships.

4.2.2 For surface type self-elevating units in the afloat conditions, the angles of inclination are to be in accordance with Table 1.3.2 in Pt 5, Ch 1,3.7 of the Rules for Ships.

4.2.3 For both column-stabilised and self-elevating units, the angles of inclination are to be in accordance with Tables 1.3.3 and 1.3.4, respectively, in Pt 5, Ch 1,3.7.

4.3 Bilge systems and cross flooding arrangements

4.3.1 For all unit types with accommodation for more than 12 persons who are not crew members, the requirements of Pt 3, Ch 4,3 are to be complied with as applicable.

4.4 Jacking gear machinery

4.4.1 For all types of self-elevating units, the number of jacking cycles expected to be seen during the unit's intended design life will need to be specially considered in the design of the jacking gear machinery. Relevant calculations will be required to be submitted, taking into account the expected number of jacking cycles during the unit's intended design life.

■ *Section 5* Control and electrical engineering

5.1 Application

5.1.1 For surface type units, the control and electrical engineering requirements are to be in accordance with Part 6 of the Rules for Ships, and are to be complied with as applicable.

5.1.2 For surface type self-elevating units, the control and electrical engineering requirements are to be in accordance with Part 6 of the Rules for Ships. Aspects which relate to the specialised offshore function of the unit will be considered on the basis of Pt 6, Ch 1 and Ch 2 and are to be complied with as applicable.

5.1.3 For both column-stabilised and self-elevating units, the main and auxiliary machinery requirements are to be in accordance with Part 6 and are to be complied with as applicable.

5.1.4 For all unit types, due account should be taken of the unit type and operational role when applying these requirements.

5.2 Angle of inclination

5.2.1 For surface type units, the angles of inclination are to be in accordance with Table 2.1.1 in Pt 6, Ch 2,1.9, of the Rules for Ships.

5.2.2 For surface type self-elevating units in the afloat conditions, the angles of inclination are to be in accordance with Table 2.1.1 in Pt 6, Ch 2,1.9 of the Rules for Ships.

5.2.3 For both column-stabilised and self-elevating units, the angles of inclination are to be in accordance with Table 2.1.1 in Pt 6, Ch 2,1.9.

5.3 Emergency source of electrical power

5.2.1 For all unit types with accommodation for more than 50 persons who are not crew members, the requirements of Pt 3, Ch 4,4.2 are to be complied with as applicable.

■ *Section 6* Safety systems, hazardous areas and fire

6.1 Application

6.1.1 For all unit types, the safety systems, hazardous areas and fire safety requirements are to be in accordance with the requirements of Part 7, and are to be complied with as applicable.

6.1.2 The requirements of Pt 7, Ch 1,9.1, are not applicable to surface type units and surface type self-elevating units. For these unit types, the requirements of Pt 3, Ch 11,9 of the Rules for Ships are to be complied with as applicable.

6.1.3 For surface type self-elevating units, the remaining requirements in Part 7 for surface type units are to be complied with as applicable.

6.1.4 For all unit types, due account should be taken of the unit type and operational role when applying these requirements.

■ *Section 7* Corrosion control

7.1 Application

7.1.1 For all unit types, the corrosion control requirements are to be in accordance with Part 8 and are to be complied with as applicable.

7.1.2 The minimum corrosion protection requirements for external structural steel work for surface type self-elevating units are to comply with Table 1.1.1 in Pt 8, Ch 1. The unit's main hull and all structure above the splash zone are to comply with the requirements for a surface type unit. The legs, footings and mats for these units are to comply with the requirements for a self-elevating unit.

■ *Section 1* Integrated Software Intensive System – 'ISIS' notation

1.1 General

1.1.1 Integrated Software Intensive System class notation **ISIS** may be assigned where an integrated computer system in compliance with Pt 6, Ch 1,6 of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships) provides fault tolerant control and monitoring functions for one or more of the following services:

- Propulsion and auxiliary machinery.
- Dynamic positioning systems.
- Positional mooring systems.
- Ballast systems.
- Process and utilities.
- Drilling equipment.
- Product storage and transfer systems.
- Well control system.
- Pollution control system.
- Jacking system for self-elevating unit.
- Cantilever skidding system for drilling unit.
- Power Management System (PMS).
- Zone Management Systems (ZMS) (for all equipment where applicable).
- Mud and cement management system.

1.2 General requirements

1.2.1 The Integrated Software Intensive System is to comply with the programmable electronic system requirements of Pt 6, Ch 1,2.10 to 2.13 of the Rules for Ships and the control and monitoring requirements of the Rules applicable to a particular equipment, machinery or systems.

1.2.2 Alarm and indication functions required by 2.4 are to be provided by the integrated computer control system in response to the activation of any safety function for associated machinery. Systems providing the safety functions are in general to be independent of the integrated computer system, *see also* Pt 6, Ch 1,2.14.7 of the Rules for Ships.

1.3 Programmable electronic systems – Additional requirements for integrated systems

1.3.1 The requirements of Pt 6, Ch 1,2.14.2 to 2.14.7 of the Rules for Ships apply to integrated systems providing control, alarm or safety functions in accordance with the Rules, including systems capable of independent operation interconnected to provide co-ordinated functions or common user interfaces. Examples include integrated machinery control, alarm and monitoring systems, power management systems and safety management systems providing a grouping of fire, passenger, crew or ship safety functions, *see* Pt 6, Ch 2,17 to 19 of the Rules for Ships.

1.3.2 System integration is to be managed by a single designated party, and is to be carried out in accordance with a defined procedure identifying the roles, responsibilities and requirements of all parties involved. This procedure is to be submitted for consideration where the integration involves control functions for essential services or safety functions including fire, passenger, crew, and ship safety.

1.3.3 The system requirements specification, *see* Pt 6, Ch 1,1.2.5 of the Rules for Ships, is to identify the allocation of functions between modules of the integrated system, and any common data communication protocols or interface standards required to support these functions.

1.3.4 Reversionary modes of operation are to be provided to ensure safe and graceful degradation in the event of one or more failures. In general, the integrated system is to be arranged such that the failure of one part will not affect the functionality of other parts, except those that require data from the failed part.

1.3.5 Where the integration involves control functions for essential services or safety functions, including fire, passenger, crew, and ship safety, a Failure Mode and Effects Analysis (FMEA) is to be carried out in accordance with IEC 60812, or an equivalent and acceptable National or International Standard and the report and worksheets submitted for consideration. The FMEA is to demonstrate that the integrated system will 'fail-safe', *see* Pt 6, Ch 1,2.4.6 and 2.5.4 of the Rules for Ships, and that essential services in operation will not be lost or degraded beyond acceptable performance criteria where specified by these Rules.

1.3.6 The quantity and quality of information presented to the operator are to be managed to assist situational awareness in all operating conditions. Excessive or ambiguous information that may adversely affect the operator's ability to reason or act correctly is to be avoided, but information needed for corrective or emergency actions is not to be suppressed or obscured in satisfying this requirement.

1.3.7 Where information is required by the Rules or by National Administration requirements to be continuously displayed, the system configuration is to be such that the information may be viewed without manual intervention, e.g., the selection of a particular screen page or mode of operation. *See also* Pt 6, Ch 1,2.10.16 of the Rules for Ships.

1.4 Operator stations

1.4.1 The requirements for the operator stations are given in Pt 6, Ch 1,6.3 of the Rules for Ships, which are to be complied with.

1.4.2 Additions or amendments to these requirements are given in 6.3.3.

1.4.3 Where the integrated computer control system is arranged such that control and monitoring functions may be accessed at more than one operator station, the selected mode of operation of each station (e.g., in control, standby, etc.) is to be clearly indicated, *see also* 2.2.

■ *Section 2* Systems engineering principles

2.1. General – Scope and objectives

2.1.1 The requirements of this Section aim to ensure that risks to offshore safety and the environment, stemming from the introduction of integrated software intensive systems, are addressed insofar as they affect the objectives of classification. Hereafter, integrated software intensive system includes all systems listed in 1.1.1.

2.1.2 The requirements of this Section are to be satisfied where an integrated software intensive systems is required to be developed, constructed, installed, integrated and tested in accordance with LR's Rules and Regulations and for which the corresponding machinery class notation is to be assigned, *see* Pt 1, Ch 2,2.5.

2.1.3 It is to be noted that as well as the requirements of this Section, the general requirements of LR's Rules and Regulations are also to be satisfied as far as they are applicable.

2.1.4 Compliance with ISO 15288 *Systems and Software Engineering – System Life Cycle Processes* or an acceptable equivalent National Standard may be accepted as meeting the requirements of Pt 6, Ch 1,2.3 to 2.12 of the Rules for Ships.

2.2 Information to be submitted

2.2.1 The information described in 2.2.2 and 2.2.3 is to be submitted for consideration.

2.2.2 General description detailing the extent of the integrated software intensive system, the offshore unit services it is to provide, its operating principles, and its functionality and capability when operating in the environment to which it is likely to be exposed under both normal and foreseeable abnormal conditions. The general description is to be supported by the following information as applicable:

(a) System block diagram.
(b) Piping and instrumentation diagrams, communication networks.
(c) Description of operating modes, including:
start-up;
shut-down;
automatic:
reversionary;
manual, and
emergency.
(d) Description of safety related arrangements, including:
safeguards;
automatic safety systems; and
interfaces with offshore units safety systems.
(e) Description of connections to other offshore unit machinery, equipment and systems, including:
electrical;
mechanical;
fluids;
automation;
communication network; and
protocols of the network.
(f) Plans of physical arrangements, including:
location;
operational access; and
maintenance access.
(g) Operating manuals, including:
instructions for start-up;
operation;
shut-down and emergency;
instructions and frequency for maintenance;
instructions for adjustments to the performance;
parameters and functionality; and
details of risk mitigation arrangements.
(h) Maintenance manuals, including:
Instructions for routine maintenance or repair following failure.
Instructions for software configuration management such as upgrading and modification.
Disposal of components and recommended spares inventory.

2.2.3 Project process documentation including:

(a) Project management plan, *see* 2.3.
(b) Quality assurance plan, *see* 2.4.
(c) Risk management plan, *see* 2.5.
(d) Configuration management plan, *see* 2.6.
(e) Requirements definition document, *see* 2.9.
(f) Design definition document, *see* 2.8.
(g) Implementation plan, *see* 2.9.
(h) Integration plan, *see* 2.10.
(j) Verification plan, *see* 2.11.
(k) Validation plan, certification and survey, *see* 2.12.

2.3 Project management

2.3.1 A project management procedure is to be established in order to define and manage the key project processes. The project processes are to include the those described in Pt 6, Ch 1,2.4 to 2.12 of the Rules for Ships.

2.3.2 For the entire project, and each of the processes within the project, the project management procedure is to define the following:

(a) Activities to be carried out.
(b) Required inputs and outputs.
(c) Roles of key personnel.
(d) Responsibilities of key personnel.
(e) Competence of key personnel.
(f) Schedules for the activities.
(g) Roles and responsibilities of stakeholders including Owner, Operator, Shipyard, System Integrator, Supplier or Subcontractor for each required activity of project processes from 2.3 to 2.12.

2.4 Quality assurance

2.4.1 A quality assurance procedure is to be established in order to ensure that the quality of the integrated software intensive system is in accordance with a defined quality management system that is acceptable to LR.

2.4.2 The procedure is to define the specific quality controls to be applied during the project in order to satisfy the requirements of the quality management system.

2.4.3 The quality management system is to satisfy the requirements of ISO 9001 *Quality management systems.* Requirements and software development is to satisfy the requirements of ISO 90003 *Software engineering – Guidelines for the application of ISO 9001 to computer software*, or other equivalent acceptable National Standard.

2.5 Risk management

2.5.1 A risk management procedure is to be established in order to ensure that any risks stemming from the introduction of the integrated software intensive system are addressed, in particular risks affecting:

(a) The structural strength and integrity of the offshore unit's hull.
(b) The safety of integrated software intensive system onboard of the offshore unit.
(c) The safety of crew.
(d) The reliability of essential and emergency systems.
(e) The environment.
(f) Offshore drilling operations with introduction of integrated software intensive systems.

2.5.2 The procedure is to consider the hazards associated with development, integration, installation, operation, maintenance and disposal, both with the integrated software intensive system functioning correctly and following any reasonably foreseeable failure.

2.5.3 The procedure is to take account of stakeholder requirements, *see* 2.7.

2.5.4 The procedure is to take account of design requirements, *see* 2.8.

2.5.5 The procedure is to ensure that hazards are identified using acceptable and recognised hazard identification techniques, *see* 2.5.9 to 2.5.14, and that the effects of the following influences are considered:

(a) Offshore unit operations, including:
    Underway, manoeuvring, pilotage, docking, alongside and maintenance, jacking or dynamic positioning, well drilling, well completion, well control, training exercises, emergency abandon, commissioning and trials.
(b) Offshore unit conditions under normal and reasonably foreseeable abnormal operating conditions arising from failures or misuse of equipment or systems onboard of offshore unit, including:
    Normal operation, blackout, loss of position, fire in a single compartment, explosion in a single compartment and flooding of a single compartment.
(c) Configuration and modes of operation provided for the intended control of integrated software intensive system, including:
    Start-up, running, shut-down, automatic, reversionary, manual and emergency.
(d) Environmental conditions, including:
    Temperature, pressure, humidity, water spray, salt mist, vibration, shock, inclination, vocanic activities, seabed conditions, hurricane or storm, subsea acoustic noise, electrical fields and magnetic fields.
(e) Dependencies, including:
    Power, fuel, air, cooling, heating, mud, cement, data, and human input.
(f) Environmental impact of the offshore unit throughout its lifecycle, including:
    Emissions to air, discharges to water, noise and waste products.
(g) Failures, including:
    Human error, supply failure, system, software, communication network, machinery, equipment and component failure, random, systematic and common cause failures.

2.5.6 The procedure is to ensure that risks are analysed using acceptable and recognised Risk Based Analysis techniques, *see* 2.5.9 to 2.5.14, and that the following effects are considered:

(a) Local effects: Loss of function, component damage, fire, explosion, electric shock, harmful releases and hazardous releases.
(b) End effects on: Loss of services essential to the safety of the offshore unit, services essential to the safety of personnel onboard of offshore unit and services essential to the protection of the environment.

2.5.7 The procedure is to ensure that risks are eliminated wherever possible. Risks which cannot be eliminated are to be mitigated as necessary.

2.5.8 Details of risks, and the means by which they are mitigated, are to be included in the operating manual, *see* 2.2.2.

2.5.9 Risk Based Analysis (RBA) technique is to be selected from IEC/ISO 31010 *Risk Management – Risk Assessment Techniques*. The technique selected is to be carried out in accordance with the relevant International Standard or applicable National Standard and with 2.5.10 to 2.5.14. A justification is to be provided which demonstrates the suitability of the Standard and analysis technique chosen.

2.5.10 The RBA is to demonstrate that suitable risk mitigation has been achieved for all normal and foreseeable abnormal conditions. The scope of analysis required for each system is defined in 2.5.11 to 2.5.14 and in the respective parts of the Rules.

2.5.11 The RBA is to be organised in terms of items of equipment and function. The effects of item failures or damage at stated level and at higher levels are to be analysed to determine the effects on the system as a whole. Actions for mitigation are to be determined.

2.5.12 RBA is to:

(a) Identify the equipment or sub-system and their mode of operation;
(b) Identify potential failure modes and damage situations and their causes;
(c) Evaluate the effects on the system of each failure mode and damage situation;
(d) Identify measures for reducing the risks associated with each failure mode;
(e) Identify measures for failure mitigation; and
(f) Identify trials and testing necessary to prove conclusions.

2.5.13 At sub-system level it is acceptable, for the purpose of these Rules, to consider failure of equipment items and their functions, e.g., failure of a pump to produce flow or pressure head. It is not required that the failure of components within that pump be analysed. In addition, failure need only be dealt with as a cause of failure of the pump.

2.5.14 Where RBA is used for consideration of systems that depend on software based functions for control or co-ordination, the analysis is to investigate failure of the function rather than a specific analysis of the software code.

2.6 Configuration management

2.6.1 A configuration management procedure is to be established in order to ensure traceability of the configuration of the integrated software intensive system, its subsystems and its components.

2.6.2 The procedure is to identify items essential for the safety or operation of the integrated software intensive system (configuration control items) which could foreseeably be changed during the lifetime of the integrated software intensive system, including:

(a) Documentation.
(b) Software.
(c) Sensors.
(d) Actuators.
(e) Instrumentation.
(f) Valves.
(g) Pumps.
(h) BOP stacks.

2.6.3 The procedure is to take account of the design requirements, *see* 2.8.

2.6.4 The procedure is to include items used to mitigate risks, *see* 2.5.

2.6.5 The procedure is to ensure that any changes to configuration control items are:

(a) Identified.
(b) Recorded.
(c) Evaluated.
(d) Approved.
(e) Incorporated.
(f) Verified.

2.6.6 The procedure is to specify the required software testing for any changes to configuration control items for the whole lifecycle of the integrated software intensive system.

2.7 Requirements definition

2.7.1 A requirements definition procedure is to be established in order to define the functional behaviour and performance throughout the whole lifecycle of the integrated software intensive system required by individual stakeholders, in the environments to which the integrated software intensive system is likely to be exposed under both normal and foreseeable emergency conditions.

2.7.2 The procedure is to take account of requirements resulting from key stakeholders, including:

(a) Owner.
(b) Operator.
(c) Crew.
(d) Shipyard.
(e) Systems integrator.
(f) Maintenance personnel.
(g) Surveyors.
(h) Manufacturers and suppliers.
(j) National Administration.
(k) LR.

2.7.3 The procedure is to take account of requirements resulting from the following influences:

(a) Offshore unit operations, *see* 2.5.5(a).
(b) Ship conditions, *see* 2.5.5(b).
(c) Environmental conditions, *see* 2.5.5(d).
(d) Applicable provisions, including:
    Statutory legislation;
    classification requirements;
    international standards;
    national standards; and
    codes of practice.
(e) Expected users, including:
    Multi-national users with a range of national languages and cultures
    fatigued users;
    users without dedicated training; and
    maintenance and survey personnel.
(f) Design, construction and operational constraints, including:
    Effect of particular design decisions or component choices on other aspects of design, risk and production engineering compromises, verification, integration and validation considerations, maintenance and disposal, and changes in use.

2.7.4 The procedure is to specify the functional behaviour and performance requirements and is to identify the source of the requirements.

2.7.5 The requirements specification is to fully specify, either directly or by reference to other submitted documents, all external interfaces between the software product and other software or hardware.

2.7.6 The procedure is to detail required functions the integrated software intensive system is to perform under both normal and foreseeable abnormal conditions.

2.7.7 The procedure is to define specific boundary conditions of each required function of the integrated software intensive system.

2.7.8 The procedure is to ensure overall integrity of the system requirements through verification and analysis of integrity of sets of requirements.

2.8 Design definition

2.8.1 A design definition procedure is to be established in order to define the requirements for the design of the integrated software intensive system which satisfies stakeholder requirements, quality assurance requirements, risk mitigate requirements and complies with basic internationally recognised design requirements for safety and functionality.

2.8.2 The procedure is to ensure that the design of the integrated software intensive system satisfies:

(a) Statutory legislation.
(b) LR's requirements.
(c) International Standards and Codes of Practice where relevant.

2.8.3 The procedure is to take account of stakeholder requirements, *see* 2.7.

2.8.4 The procedure is to take account of quality assurance requirements, *see* 2.4.

2.8.5 The procedure is to take account of risk management requirements, *see* 2.5.

2.8.6 The procedure is to ensure that the requirements for the design of major components and subsystems of the integrated software intensive system can be verified before and after integration.

2.8.7 The procedure is to specify the design requirements and is to identify the source of the requirements.

2.8.8 Any deviations from stakeholder requirements are to be identified, justified and accepted by the originating stakeholder, communicated to involved stakeholders and documented.

2.9 Implementation

2.9.1 An implementation procedure and technology is to be selected in order to realise specific integrated software intensive system that satisfies the design requirements of the machinery or an engineering system or integrated software intensive system through verification, *see* 2.11 and satisfies stakeholder requirements through validation, *see* 2.12.

2.9.2 The procedure and technology is to take account of quality assurance requirements, *see* 2.4.

2.9.3 The procedure and technology is to take account of design requirements, *see* 2.8.

2.9.4 Software lifecycle activities are to be carried out in accordance with an acceptable quality management system, *see* Pt 6, Ch 1,2.13.2 and 2.13.7 of the Rules for Ships. Appropriate safety related processes, methods, techniques and tools are to be applied to software development and maintenance by the manufacturer.

2.9.5 To demonstrate compliance with 2.9.4:

(a) software quality plans and safety evidence are to be submitted for consideration;
(b) an assessment inspection of the manufacturer's completed development is to be carried out by LR. The inspection is to be tailored to verify application of the standards and codes used in software safety assurance accepted by LR; and
(c) for software development lifecycle, an evidence of satisfying internationally recognised standards and practices that are acceptable to LR is to submit for consideration of satisfying 2.9.4(b).

2.10 Integration

2.10.1 An integration procedure is to be established in order to ensure that the integrated software intensive system is assembled in a sequence which allows verification of individual system, individual subsystems and major components following integration in advance of validating the entire integrated software intensive system.

2.10.2 The procedure is to take account of the verification requirements, *see* 2.11.

2.10.3 The procedure is to identify the subsystems and major components, the sequence in which they are to be integrated, the points in the project at which integration is to be carried out, and the points in the project at which verification is to be carried out.

2.11 Verification

2.11.1 A verification procedure is to be established in order to ensure that systems, subsystems and major components of the integrated software intensive system satisfy their design requirements.

2.11.2 The procedure is to verify design requirements, *see* 2.8.

2.11.3 The procedure is to identify the requirements to be verified, the means by which they are to be verified, the verification methods and techniques, and the points in the project at which verification is to be carried out.

2.11.4 The procedure is to be based on one or a combination of the following activities as appropriate:
(a) Design review.
(b) Product inspection.
(c) Process audit.
(d) Product testing.

2.12 Validation

2.12.1 A validation procedure is to be established in order to ensure the functional behaviour and performance of the integrated software intensive system meets with its functional and performance requirements in its intended operational environment.

2.12.2 The procedure is to validate stakeholder requirements, *see* 2.7.

2.12.3 The procedure is to validate arrangements required to mitigate risks, *see* 2.5.

2.12.4 The procedure is to validate the traceability of the configuration control items, *see* 2.6.

2.12.5 The procedure is to identify the requirements to be validated, the means by which they are be validated and the points in the project at which validation is to be carried out, including:
(a) Factory acceptance testing.
(b) Integration testing.
(c) Commissioning.
(d) Sea trials.
(e) Survey.

■ *Section 3* **Software**

3.1 General, scope and objectives

3.1.1 Where software is used as the implementation technology for the ISIS then the additional requirements in 3.1.2 to 3.1.9 are to be applied. Where a proposed activity is not undertaken, justification is to be documented and submitted.

3.1.2 A plan for the production of software is to be produced and is to include, but not limit to, the elements listed below.
(a) A full list of software components being developed and, for each, what is required to be produced including code artefacts, tools, specifications, design models, and documentation.
(b) The identification of the deliverables, including those for the purposes of late project phase activities such as boat/platform integration, boat trials, operations and maintenance.
(c) Details of any work that is being subcontracted and how the subcontract will be managed, including specifically ensuring that the Software Development Plan for the software lifecycle will be adhered to.
(d) An identification of the principal project risks arising from the development work.
(e) A definition of the software lifecycle is to be deployed.
(f) The processes, methods, techniques and tools to be used for each phase of the software lifecycle, including:
- pedigree of chosen language, tools and design methods;
- the identification of specific software architecture and software design features appropriate to the reliance being placed on the software; and
- verification performed at each stage of the lifecycle including measures to show that all the requirements, have been correctly translated or implemented by the lifecycle phase activities.

(g) Identify the key personnel in the software development team and in any subcontractors, and their responsibilities. The competency of software development team, especially experience of using the processes, methods, techniques and tools to be used.
(h) Analysis of the software architecture and the software design to confirm that the specific design features which are implemented by functions to satisfy the requirements will work as intended in all modes of operation and failure conditions.

(j) Details of the code implementation and coding standards to be applied to ensure that the software code will be reliable and maintainable.

(k) Validation activities to demonstrate that the functions of the software specifically implemented to satisfy the requirements will operate as intended in all feasible operating scenarios, including:
- testing to show that hazard mitigations work as intended;
- testing and demonstration of safe and acceptable behaviour even in unexpected states, modes and failure conditions; and
- testing that functions implemented to satisfy the requirements work in all credible operating scenarios.

3.1.3 Additional requirements for verification and validation of software components in software-based control systems that handles safety and critical operational functions are listed in 3.1.4 to 3.1.9.

3.1.4 Evidence of satisfying the requirements of ISO/IEC 21119: *Software and Systems Engineering – Software Testing*, or ISO/IEC 61508-3 *Functional safety of electrical/electronic/programmable*, is to meet requirements 3.1.5 to 3.1.9 in this sub-Section.

3.1.5 Evidence is to be submitted that software test scenarios and software test results cover all of the independent paths. Evidence is to be submitted that test results and software static tests on control flow, data flow and design review are to be used to analyse the quality of software code.

3.1.6 For the purpose of black-box testing, evidence is to be submitted that test results, methods, techniques and tools that are acceptable to LR are applied before and after integrations.

3.1.7 Evidence is to be submitted that test results and software tests listed below are to be applied for software verification:

(a) Dynamic analysis and testing for:
  Boundary values, structural test coverage (entry points) 100 per cent and structural test coverage (statements) 100 per cent.

(b) Static analysis and testing for:
  Control flow, data flow and design review.

(c) Functional and black box testing on:
  Equivalence classes and input partition testing including boundary value analysis.

(d) Performance testing for:
  Response timings and memory constraints, performance requirements.

(e) Data recording and analysis.

(f) Regression testing.

3.1.8 Evidence is to be submitted that test results and software tests listed below are to be applied for software validation:
- Functional and black box testing.

3.1.9 Evidence that coding reviews have been undertaken is to be submitted.

Section A1
Codes and Standards

A1.1 Abbreviations

A1.1.1 The following abbreviations are used in this Appendix:

AISC	American Institute of Steel Construction.
ANSI	American National Standards Institute.
API	American Petroleum Institute.
ASME	American Society of Mechanical Engineers.
BS	British Standard.
CSA	Canadian Standards Association.
DIN	Deutsches Institut für Normung.
FEM	Fédération Européenne de la Manutention.
IP	International Petroleum.
ISO	International Standards Organisation.
NACE	National Association of Corrosion Engineers.
NS	Norwegian Standard.
NFPA	National Fire Protection Association.
TBK	Norwegian Pressure Vessel Committee.
UKOOA	United Kingdom Offshore Operators Association.

A1.2 Recognised Codes and Standards

A1.2.1 The following Codes and Standards are recognised by LR in connection with the design, construction and installation of machinery, equipment and systems which form part of the drilling plant facility, production and process plant facility and riser systems installed on offshore units as appropriate. Codes are also given for structural components, concrete structures, bearings and formulations used in positional mooring systems.

A1.2.2 The following National and International Codes and Standards listed are subject to change/deletion without notice. The latest edition of a Code or Standard, with all applicable addenda, current at the date of contract award should be used.

A1.2.3 When requested, other National and International Codes and Standards may be used after special consideration and agreement by LR.

A1.2.4 **Blow out prevention**:

API Spec. 16A	*Specification for Drill through Equipment.*
API S 53	*Blowout Prevention Equipment Systems for Drilling Operations.*
API RP 16E	*Design of Control Systems for Drilling Well Control Equipment.*

A1.2.5 **Lifting appliances for blow out preventer and burner boom, and other equipment**:

API Spec 2C	*Specification for Offshore Pedestal Mounted Cranes.*
ASME B30.20	*Below the Hook Lifting Devices.*
API Spec 8C	*Drilling and Production Hoisting Equipment.*
FEM 1.001	*Section-1: Heavy lifting appliances – Rules for the design of Hoisting Appliance Methods of Strength Calculation.*
ISO 2374	*Lifting Appliances – Range of Maximum Capacities for Basic Models.*
ISO 10245	*(all parts) Cranes – Limiting and indicating devices.*
ISO 13534	*Petroleum and natural gas industries – Drilling and production equipment – Inspection, maintenance, repair and remanufacture of hoisting equipment.*
ISO 13535	*Petroleum and natural gas industries – Drilling and production equipment – Hoisting equipment.*

LR's *Code for Lifting Appliances in a Marine Environment.*

A1.2.6 **Derrick**:

API 4E	*Drilling and Well Servicing Structures.*

A1.2.7 **Drilling equipment**:

API Spec. 7	*Specification for Rotary Drilling Equipment.*
API RP 7G	*Drill Stem Design and Operating Limits.*
API Spec. 8A and 8C	*Drilling and Production Hoisting Equipment.*
API RP 8B	*Hoisting Tool Inspection and Maintenance Procedures.*
API Spec. 9A	*Wire Rope.*
API RP 9B	*Application, Care and Use of Wire Rope for Oil Field Service.*
ISO 10405	*Petroleum and natural gas industries – Care and use of casing and tubing.*
ISO 10407	*Petroleum and natural gas industries – Drilling and production equipment – Drill stem design and operating limits.*
ISO 10426	*Petroleum and natural gas industries – Cements and materials for well cementing.*
ISO 11960	*Petroleum and natural gas industries – Steel pipes for use as casing or tubing for wells.*
ISO 11961	*Petroleum and natural gas industries – Steel pipes for use as drill pipe – Specification.*
ISO 13500	*Hydraulic fluid power – Determination of particulate contamination by automatic counting using the light extinction principle.*
ISO 13533	*Petroleum and natural gas industries – Drilling and production equipment – Drill-through equipment.*
ISO 14693	*Petroleum and natural gas industries – Drilling and well-servicing equipment.*

ISO 13678	*Petroleum and natural gas industries – Evaluation and testing of thread compounds for use with casing, tubing and line pipe.*
ISO 13680	*Petroleum and natural gas industries – Corrosion-resistant alloy seamless tubes for use as casing, tubing and coupling stock – Technical delivery conditions.*
FEM 1001 3rd Edition:	*Rules for the Design of Hoisting Appliances, Section 1, Booklets 3 to 8.*

A1.2.8 **Wellhead equipment**:

API Spec. 6A & ISO 10423	*Wellhead and Christmas Tree: Equipment*.
API Spec. 14D	*Wellhead Surface Safety Valves and Underwater Safety Valves for Offshore Service.*
API RP 14B	*Design, Installation and Operation of Subsurface Safety Valve Systems.*
API RP 17D	*Specification for Subsea Wellhead and Christmas Tree Equipment.*

A1.2.9 **Piping**:

ASME B16.47	*Large Diameter Steel Flanges: NPS 26 Through NPS 60.*
ASME B16.5	*Pipe Flanges and Flanged Fittings.*
ANSI/ASME B31.3	*Process piping.*
BS 3351	*Specification for Piping Systems for Petroleum Refineries and Petrochemical Plants.*
ISO 13703	*Petroleum and natural gas industries – Design and installation of piping systems on offshore production platforms.*
API RP 14E	*Design and Installation of Offshore Production Platform Piping Systems.*
API RP 17B	*Flexible Pipe.*
API RP 520	*Design and Installation of Pressure Relieving Systems in Refineries.*
API RP 521	*Guide for Pressure Relieving and Depressurising Systems.*
API RP 16C	*Specification for Choke and Kill Systems.*
ISO 10434	*Bolted bonnet steel gate valves for the petroleum, petrochemical and allied industries.*
ISO 13623	*Petroleum and natural gas industries – Pipeline transportation systems.*
ISO 13847	*Petroleum and natural gas industries – Pipeline transportation systems – Welding of pipelines.*
ISO 14313	*Petroleum and natural gas industries – Pipeline transportation systems – Pipeline valves.*
ISO 15649	*Petroleum and natural gas industries – Piping.*
ISO 15761	*Steel gate, globe and check valves for sizes DN 100 and smaller, for the petroleum and natural gas industries.*
UKOOA	*Specification and Recommended Practice for the Use of GRP Piping Offshore.*

A1.2.10 **Riser and flow lines**:

API RP 2RD	*Riser Design.*
API RP 16R	*Design Rating and Testing of Marine Drilling Riser Couplings.*
API RP 16Q	*Design and Operation of Marine Drilling Riser Systems.*
API Bul 2J	*Comparison of Marine Drilling Riser Analysis.*
API RP 17B	*Recommended Practice for Flexible Pipe.*
API Spec.17J	*Specification for Unbonded Flexible Pipe.*
BS PD 8010	*Code of Practice for Pipelines, Part 3, Pipelines Subsea: Design, Construction and Installation.*
ISO 3183	*Petroleum and natural gas industries – Steel pipe for pipeline transportation systems*.
ISO 10414	*Petroleum and natural gas industries – Field testing of drilling fluids.*
ISO 10426	*Petroleum and natural gas industries – Cements and materials for well cementing.*
ISO 10427	*Petroleum and natural gas industries – Equipment for well cementing.*
ISO 11960	*Petroleum and natural gas industries – Steel pipes for use as casing or tubing for wells.*
ISO 15156	*Petroleum and natural gas industries – Materials for use in H_2S-containing environments in oil and gas production.*
ISO 15463	*Petroleum and natural gas industries – Field inspection of new casing, tubing and plain-end drill pipe.*
ISO 16070	*Petroleum and natural gas industries – Downhole equipment – Lock mandrels and landing nipples.*
ISO 18165	*Petroleum and natural gas industries – Performance testing of cementing float equipment.*
ISO 15590	*Petroleum and natural gas industries – Induction bends, fittings and flanges for pipeline transportation systems.*

A1.2.11 **Pressure vessels/fired units/heat exchangers**:

TBK-1-2	*General Rules for Pressure Vessels.*
ASME Section VIII, Div. 1 and 2	*Rules for Construction of Pressure Vessels.*
PD 5500	*Unfired Fusion Welded Pressure Vessel.*
ASME Section 1	*Power Boilers.*
ASME Section IV	*Heating Boilers.*
ASME BPVC Sec I	*Boiler And Pressure Vessel Code, Section I, Rules For The Construction Of Power Boilers.*
ASME BPVC Sec IX	*Boiler And Pressure Vessel Code, Section Ix, Welding And Brazing Qualifications.*
ASME BPVC Sec V	*Boiler And Pressure Vessel Code, Section V, Nondestructive Examination.*
ASME BPVC Sec VIII-1	*Boiler And Pressure Vessel Code, Section Viii, Rules For The Construction Of Pressure Vessels, Division 1.*

ASME BPVC Sec VIII-2	*Boiler And Pressure Vessel Code, Section Viii, Rules For The Construction Of Pressure Vessels, Division 2 – Alternative Rules.*
ASME BPVC Sec VIII-3	*Boiler And Pressure Vessel Code, Section Viii, Rules For The Construction Of Pressure Vessels, Division 3 – Alternative Rules For Construction Of High Pressure Vessels.*
BS 2790	*Shell Boiler of Welded Construction.*
TEMA	*Standards of the Tubular Exchangers Manufacturers Association.*
EEMUA	*PUB No 143 Recommendations for Tube End Welding: Tubular Heat Transfer Equipment (Part 1 – Ferrous Materials).*
API RP 530	*Calculation of Heater. Tube Thickness in Petroleum Refineries.*
API 660	*Shell and tube heat exchangers for general refinery service.*
API 661	*Air Cooled Heat Exchangers for General Refinery Service.*
API 662	*Plate Heat Exchanger for General Refinery Services.*
BS EN 12952	*Water-Tube Steam Generating Plant.*
ISO 13706	*Petroleum, petrochemical and natural gas industries – Air-cooled heat exchangers.*
ISO 15547	*Petroleum, petrochemical and natural gas industries – Plate-type heat exchangers.*
ISO 13705	*Petroleum, petrochemical and natural gas industries – Fired heaters for general refinery service.*
ISO 16812	*Petroleum, petrochemical and natural gas industries – Shell-and-tube heat exchangers.*

A1.2.12 **Process plant equipment**:

API 610	*Centrifugal Pumps for General Refinery Service.*
API 615	*Sound Control of Mechanical Equipment for Refinery Service.*
API 617	*Centrifugal Compressors for General Refinery Services.*
API RP 14C	*Recommended Practices for Analysis, Design, Installation and Testing of Basic Surface Safety Systems on Offshore Production Platforms.*
API RP 550	*Recommended Practice: Manual on Installation of Refinery Instruments and Control Systems, Parts 1 to 4.*
API Std 613	*Special Purpose Gear Units for Petroleum, Chemical, and Gas Industry Services.*
API Std 614	*Lubrication, Shaft-Sealing, and Control-Oil Systems and Auxiliaries for Petroleum, Chemical and Gas Industry Services.*
API Std 618	*Reciprocating Compressors for Petroleum, Chemical, and Gas Industry Services.*
API Std 619	*Rotary Type Positive Displacement Compressors for Petroleum, Chemical, and Gas Industry Services.*
API Std 620	*Design and Construction of large, welded, low-pressure storage tanks.*
API Std 650	*Welded steel tanks for oil storage.*
API Std 670	*Machinery Protection Systems.*
API Std 671	*Special purpose Couplings for Petroleum, Chemical and Gas Industry Services.*
API Std 672	*Packaged, integrally geared, centrifugal air compressors for petroleum, chemical and gas industry services.*
API Std 673	*Centrifugal Fans for Petroleum, Chemical and Gas Industry Service.*
API Std 674	*Positive displacement pumps – Reciprocating.*
API Std 675	*Positive displacement pumps – Controlled volume.*
API Std 676	*Positive displacement pumps – Rotary.*
API Std 681	*Liquid Ring Vacuum Pumps and Compressors for Petroleum, Chemical, and Gas Industry Services.*
API Std 682	*Shaft Sealing Systems for Centrifugal and Rotary Pumps.*
API 616	*Combustion Gas Turbines for General Refinery Service.*
ASME B73.1	*Specification for Horizontal End Suction Centrifugal Pumps for Chemical Process.*
ASME B73.2M	*Specification for Vertical In-Line Centrifugal Pumps for Chemical Process.*
ISO 2314	*1973 Gas Turbine Acceptance Tests.*
ISO 2858	*End-suction centrifugal pumps (rating 16 bar) – Designation, nominal duty point and dimensions.*
ISO 2954	*Mechanical vibration of rotating and reciprocating machinery – Requirements for instruments for measuring vibration severity.*
ISO 3046	*(all parts) Reciprocating internal combustion engines – Performance.*
ISO 3977	*(all parts) Gas turbines – Procurement. ISO 5199 Technical specs. for centrifugal pumps- Class II.*
ISO 9906	*Roto-dynamic pumps – Hydraulic performance acceptance tests – Grades 1 and 2.*
ISO 10431	*Petroleum and Natural Gas Industries – Pumping Units – Specification.*
ISO 10436	*Petroleum and Natural Gas Industries – General purpose steam turbines for refinery service.*
ISO 10440	*(all parts) Petroleum and Natural Gas Industries – Positive displacement-rotary type compressors.*
ISO 10441	*Petroleum, petrochemical and natural gas industries – Flexible couplings for mechanical power transmission – Special-purpose applications.*
ISO 13707	*Petroleum and natural gas industries – Reciprocating compressors.*
ISO 14691	*Petroleum and natural gas industries – Flexible couplings for mechanical power transmission – General purpose applications.*

ISO 10437	*Petroleum, petrochemical and natural gas industries – Steam turbines – Special-purpose applications.*
ISO 10438	*Petroleum, petrochemical and natural gas industries – Lubrication, shaft-sealing and control-oil systems and auxiliaries.*
ISO 10439	*Petroleum, chemical and gas service industries – Centrifugal compressors.*
ISO 13631	*Petroleum and natural gas industries – Packaged reciprocating gas compressors.*
ISO 13691	*Petroleum and natural gas industries – High-speed special-purpose gear units.*
ISO 14310	*Petroleum and natural gas industries – Downhole equipment – Packers and bridge plugs.*
ISO 15136	*Downhole equipment for petroleum and natural gas industries – Progressing cavity pump systems for artificial lift.*
NFPA No. 37	*1975 Stationary Combustion Engines and Gas Turbines.*
EEMUA	*PUB No 141 Guide to the use of Noise Procedure Specification.*

A1.2.13 **General structural items (skids, support frames and trusses, helidecks, etc)**:

CAP 437	*Offshore Helicopter Landing Areas – Guidance on Standards*.
BS 5950	*Structural Use of Steelwork in Building.*
AISC	*Manual of Steel Construction – Allowable Stress Design.*
BS 2853	*The Design and Testing of Steel Overhead Runway Beams.*
BS EN 1993	*Eurocode 3: Design of Steel Structures.*
BS 6399-2	*Loads for Buildings, Code of Practice for Wind Loads.*
BS 8118	*Structural Use of Aluminium.*
API BUL 2U	*Design of Flat Plate Structures.*
AISC LRFD	*Manual of Steel Construction – Load and Resistance Factor Design.*
API RP 2A – WSD	*Recommended Practice for Planning, Design and Constructing Fixed Offshore Platforms Working Stress Design.*
BS 8100	*Lattice Towers and Masts.*
API RP 2SK	*Recommended Practice for Design and Analysis of Stationkeeping Systems for Floating Structures.*

A1.2.14 **Hazard area classification**:

API RP 500	*Classification of Locations for Electrical Installations at Petroleum Facilities.*
API RP 505	*Classification of Locations for Electrical Installations at Petroleum Facilities, Classed as Class I, Zones 0, 1 & 2.*
IP Code, Part 3	*Refining Safety Code.*
IP Code, Part 8	*Drilling and Production Safety Code for Offshore Operations.*
IP Code, Part 15	*Area Classification Code for Petroleum Installations.*
ISO 15138	*Petroleum and natural gas industries – Offshore production installations – Heating, ventilation and air-conditioning.*
ISO 17776	*Petroleum and natural gas industries – Offshore production installations – Guidelines on tools and techniques for hazard identification and risk assessment.*

A1.2.15 **Fire and safety standards:**

ISO 13702	*Petroleum and natural gas industries – Control and mitigation of fires and explosions on offshore production installations – Requirements and guidelines.*
ISO 15544	*Petroleum and natural gas industries – Offshore production installations – Requirements and guidelines for emergency response.*
NFPA No. 1	*Fire Prevention Code.*
NFPA No. 10	*Portable Extinguishers.*
NFPA No. 11	*Low-Expansion Foam.*
NFPA No. 11A	*Medium- and High-Expansion Foam Systems.*
NFPA No. 11C	*Mobile Foam Apparatus.*
NFPA No. 12	*Carbon Dioxide Systems.*
NFPA No. 12A	*Halon 1301 Systems.*
NFPA No. 13	*Sprinkler Systems.*
NFPA No. 14	*Standpipe, Hose Systems.*
NFPA No. 15	*Water Spray Fixed Systems.*
NFPA No. 16	*Deluge Foam-Water Systems.*
NFPA No. 16A	*Closed Head Foam-Water Sprinkler Systems.*
NFPA No. 17	*Dry Chem. Ext. Systems.*
NFPA No. 17A	*Wet Chem. Ext. Systems.*
NFPA No. 20	*Centrifugal Fire Pumps.*
NFPA No. 25	*Water-based Fire Protection Systems.*
NFPA No. 68	*Venting of Deflagrations.*
NFPA No. 69	*Explosion Prevention Systems.*
NFPA No. 80	*Fire Doors and Fire Windows.*
NFPA No. 170	*Fire Safety Symbols.*
NFPA No. 704	*Fire Hazards of Materials.*
NFPA No. 750	*Standard for Installation of Water Mist Fire Suppression System.*
NFPA No. 2001	*Clean Agent Ext. Systems.*
HSE OTI 95-634	*Jet Fire Resistance Test of Passive Fire Materials.*

A1.2.16 **Bearings**:

ANSI/AFBMA	*Std 11 – 1978 – Load Ratings and Fatigue Life for Roller Bearings.*
ASME 77-DE-39	*Design Criteria to Prevent Core Crushing Failure in Large Diameter Case Hardened Ball and Roller Bearings.*
BS 5512:1991/ ISO 281:1990	*Dynamic Load Ratings and Rating Life of Rolling Bearings.*
BS 5645:1987/ ISO 76:1987	*Static Load Ratings for Rolling Bearings.*
ISO 281	*Roller Bearing-Dynamic Load Ratings and Rating Life.*
ISO 10438	*(all parts) Petroleum and natural gas industries – Lubrication, shaft-sealing and control-oil systems and auxiliaries.*

A1.2.17 **Wind gust spectra formulations**:

API RP 2A — *Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms.*

Deaves D.M & Harris R.I 1978 — *A mathematical model of the structure of strong winds, CIRIA Report No. 76.*

Slettringen (Norwegian Petroleum Directorate)

A1.2.18 **Wave contour development**:

Environmental Parameters for Extreme Response: Inverse Form with Omission Factors, Winterstein et al, ISBN No. 9054103571.

A1.2.19 **Codes for concrete structures**:

BS 8110 — *Structural Use of Concrete, Parts 1, 2 and 3.*

NS 3473 — *Concrete Structures – Design Rules.*

CSA S471 — *General Requirements, Design Criteria, the Environment and Loads.*

CSA S474 — *Concrete Structures, Offshore Structures.*

ISO 19903 — *Fixed Concrete Structures.*

Other publications:

- Health and Safety Executive, Offshore Installations: *Guidance on Design, Construction and Certification*. (This guidance is no longer updated).
- Norwegian Petroleum Directorate, Guidelines relating to concrete structures to regulations relating to load bearing structures in the petroleum activities.

A1.2.20 **Subsea**:

ISO 14723 — *Petroleum and natural gas industries – Pipeline transportation systems – Subsea pipeline valves.*

ISO 13628-1 — *Petroleum and natural gas industries – Design and operation of subsea production systems – Part 1: General requirements and recommendations.*

ISO 13628-2 — *Petroleum and natural gas industries – Design and operation of subsea production systems – Part 2: Unbonded flexible pipe systems for subsea and marine applications.*

ISO 13628-3 — *Petroleum and natural gas industries – Design and operation of subsea production systems – Part 3: Through flowline (TFL) systems.*

ISO 13628-4 — *Petroleum and natural gas industries – Design and operation of subsea production systems – Part 4: Subsea wellhead and tree equipment.*

ISO 13628-5 — *Petroleum and natural gas industries – Design and operation of subsea production systems – Part 5: Subsea umbilicals.*

ISO 13628-6 — *Petroleum and natural gas industries – Design and operation of subsea production systems – Part 6: Subsea production control systems.*

ISO 13628-9 — *Petroleum and natural gas industries – Design and operation of subsea production systems – Part 9: Remotely Operated Tool (ROT) intervention systems.*

A1.2.21 **Miscellaneous**:

NACE MR0175/ ISO 15156 — *Petroleum and Natural gas industries materials for use in H_2S-containing environment in oil and gas production.*

ISO 19901-4 (2003) — *Petroleum and natural gas industries – Specific requirements for offshore structures – Part 4: Geotechnical and foundation design considerations*.

ISO 15156-1 — *Petroleum and natural gas industries – Materials for use in H_2S-containing environments in oil and gas production – Part 1: General principles for selection of cracking-resistant materials.*

ISO 15156-2 — *Petroleum and natural gas industries – Materials for use in H_2S-containing environments in oil and gas production – Part 2: Cracking-resistant carbon and low alloy steels, and the use of cast irons.*

ISO 15156-3 — *Petroleum and natural gas industries – Materials for use in H_2S-containing environments in oil and gas production – Part 3: Cracking-resistant CRAs (corrosion-resistant alloys) and other alloys.*

API RP 14H — *Use of Surface Valves and Underwater Safety Valves Offshore.*

API Spec 6FA — *Fire Test for Valves.*

API Spec 6D — *Pipeline Valves (Gate, Plug, Ball and Check Valves).*

ASME B40.100 — *Pressure Gauges and Gauge Attachments.*

ISO 14224 — *Petroleum, petrochemical and natural gas industries – Collection and exchange of reliability and maintenance data for equipment.*

ISO 15663 — *Petroleum and natural gas industries – Life cycle costing.*

ISO 13637 — *Petroleum and natural gas industries – Mooring of mobile offshore drilling units (MODUS) – Design and analysis.*

ISO 13704 — *Petroleum, petrochemical and natural gas industries – Calculation of heater-tube thickness in petroleum refineries.*

WRC Bull 107 — *Welding Research Council – Local Stresses in Spherical and Cylindrical Due to External Loading.*

WRC Bull 297 — *Welding Research Council – Local Stresses in Spherical and Cylindrical Shells Due to External Loading on nozzles – Supplement to WRC Bull 107.*

BS 6755 — *Testing of Valves: Part 2 Specification for Fire Type-Testing Requirement.*

■ *Section A2* Equipment categories

A2.1 Drilling equipment

A2.1.1 A list of usual drilling equipment with its categories is given in Table A2.1.

Table A2.1 Usual drilling equipment with its categories (*see continuation*)

Systems and types of equipment	Category	Description of equipment
1. Well protection valves with control systems		
1.1 Blow out prevention		
1.1.1 Equipment	1A	Hydraulic connector for wellhead
	1A	Ram preventers
	1A	Annular preventers
	1B	Accumulators for sub-sea stack
	1B	Sub-sea fail-safe valves in choke and kill lines
	1A	Clamp
	1B	Test stump
1.1.2 Control equipment	1A	Electrical/electronic control systems
	1A	Deadman systems
	1A	Autoshear system
	1A	Emergency disconnect system
	1B	Accumulators in control system
	1B	Welded pipes and manifolds
	II	Unwelded hydraulic piping
	II	Flexible control hoses
	II	Hydraulic hose reel
	II	Hydraulic power unit including pumps and manifold
	II	Control pads
	1B	Acoustic transportable emergency power package
	II	Control panels
1.2 Choke and kill equipment	1A	Choke manifold
	1B	All piping to and from choke manifold
	1B	Piping for choke, kill and booster lines
	1B	Flexible hoses for choke, kill and booster lines
	1B	Valves in choke, kill and booster lines
	1B	Unions and swivel joints
	1B	Emergency circulation pump – pressure side
1.3 Diverter unit	1A	Diverter house with annular valve
	1B	Diverter piping
	1B	Valves in diverter piping
	II	Control panel
	II	Hydraulic power unit including pumps and manifold
2. Marine riser with control systems	1A	Hydraulic connector
	1A	Ball joint and flexible joint
	1A	Riser sections including joints
	1B	Support ring for riser tensioning
	1A	Telescopic joint
	1B	Accumulators
	II	Hydraulic power unit including pumps and manifold
	II	Control panel
3. Heave compensation		
3.1 Tensioning system for riser and guidelines	1B	Riser tensioner
	1B	Guideline and podline tensioners
	1B	Hydro-pneumatic accumulators
	1B	Pressure vessels
	1B	Piping system
	II	Air compressors
	II	Air dryers
	II	Wire ropes for tensioning equipment
	II	Sheaves for riser tension line
	II	Sheaves for guideline and podline
	1B	Telescopic arms for tension lines
	II	Control panels
3.2 Drill string compensator	1A	Compensator
	1B	Hydro-pneumatic accumulators
	1B	Pressure vessels
	1B	Piping system including flexible hoses
	II	Air compressor
	II	Air dryer
	II	Wire ropes
	II	Sheaves
	II	Control panels

Table A2.1 Usual drilling equipment with its categories (*continued*)

Systems and types of equipment	Category	Description of equipment
4. Hoisting rotation and pipe handling		
4.1 Drilling derrick	1A	Derrick and substructure
4.2 Hoisting equipment for derrick	1B	Sheaves for crown block and travelling block
	1A	Crown block including support beams
	1B	Guide track and dolly for travelling block
	1A	Travelling block
	1A	Drilling hook
	1A	Swivel
	1B	Links
	1B	Elevators
	II	Drilling line and sand line
	1B	Deadline anchor
	1B	Drawworks including foundation
	1B	Air winches for the transport of personnel
	1B	Cranes in derrick
	1B	Cherry picker
	1B	Personal hoisting equipment
4.3 Rotary equipment	1B	Rotary table including skid adopter and driving unit
	II	Kelly
	II	Master bushing
	II	Kelly bushing
	1A	Top drive
4.4 Pipe handling	1B	Racking arms with or without lifting head
	II	Finger board
	II	Tubular chute
	II	Hydraulic cathead
	II	Mousehole powered
5. Miscellaneous equipment for drilling	1B	Manual tongs for pipe handling
	II	Power tongs for pipe handling
	II	Kelly spinner
	II	Power slips
	1B	Elevators for lifting pipe
6. Bulk storage, drilling fluid circulation and cementing		
	1A	Drilling systems controls
	1B	Hydraulic control systems
	II	Hydraulic power units including ring lines
6.1 Bulk storage	1B	Pressurised storage vessels
	1B	Piping system for pressurised bulk transport
6.2 Drilling fluid, circulation and transportation		
6.2.1 Suction and transport System II (low pressure)	II	Piping systems for mixing of drilling fluid and suction line to the drilling fluid pump
	II	Centrifugal pumps for mixing drilling fluid
6.2.2 Well circulation system (high pressure)	1B	Drilling fluid pump – pressure side
	1B	Pulsation dampers
	1B	Piping circulation of drilling fluid in the well
	1B	Standpipe manifold
	1B	Rotary hose with end connections
	1B	Kelly cocks
	1B	Non-return valve in drill string (inside BCP)
	1B	Mixing pumps
	1B	Safety valves
	1B	Circulation head
6.2.3 Mud return system on deck	II	Mud return pipe
	II	Dump tank
	II	Shale shaker
	II	Drilling fluid tanks
	II	Trip tank
	II	Desander, desilter
	1B	Degasser
	1B	Piping from degasser to burners or to ventilation
	II	Chemical mixers
	II	Agitators for drilling fluid

Table A2.1 **Usual drilling equipment with its categories** (*conclusion*)

Systems and types of equipment	Category	Description of equipment
6.2.4 Cementing	II	Centrifugal pumps for mixing of cement
	II	Piping system for mixing cement and suction line to the cement pump
	1B	Cement pump – pressure side
	1B	Pulsation dampener
	1B	Piping for cement pump discharge
	1B	Safety valves
7. Lifting system for blow out preventer	1A	Blow out preventer crane/carrier, etc.
8. Miscellaneous equipment being part of the drilling installations	*See* Table A2.2	Miscellaneous pipes, flanges, valves, unions, etc.
	1B	Pressure vessels and separators
	1B	Heat exchangers
	1B	Pumps for overhauling of wells – pressure side
	II	Other pumps
	II	Burners
	1A	Burner boom
	See Table A2.2	Safety valves for above equipment

NOTES
1. The equipment list is intended as a guide only and does not necessarily cover all the equipment items found in a drilling plant facility.
2. Equipment considered to be important for safety which is not listed in the Table will be specially considered by LR and categorised.

A2.2 Miscellaneous equipment

A2.2.1 A list of miscellaneous equipment forming part of the drilling installation is given in Table A2.2.

Table A2.2 **Miscellaneous equipment forming part of the drilling installation**

Component	Conditions	Category 1B	Category II
1. Piping	Thickness of wall > 25,4 mm.	✓	
	Design temperature > 400°C	✓	
	All welded pipes and piping systems used in Category 1A and 1B piping systems	✓	
	Pipes other than those mentioned above and pipes in Category II systems		✓
2. Flanges and couplings	Standard flanges and pipe couplings		✓
	Non-standard flanges and pipe couplings used in Category 1A and 1B piping systems	✓	
	Flanges and pipe couplings other than those mentioned above, and flanges and couplings for Category II piping systems		✓
3. Valves	Valve body welded construction with ANSI rating > 600 lbs	✓	
	Valves designed and manufactured in accordance with recognised standards		✓
4. Components of high strength material	Specified yield strength > 345 N/mm^2 or tensile strength > 515 N/mm^2	✓	

A2.3 Production equipment

A2.3.1 A list of usual production equipment with its categories is given in Table A2.3.

Table A2.3 Production equipment with its categories

Systems and types of equipment	Category	Description of equipment
1. Christmas tree and sub-sea production system	1A	Christmas tree, wellhead couplings, valves and control lines
	1A	Production manifolds and piping
	1B	Template and other floor structures
	1A	Well safety valve
	II	Electrical control module
2. Riser system		
2.1 Rigid	1A	Riser sections
	1A	Hydraulic connector unit
	1A	Ball and flexible joints
	1A	Telescopic joints
	1B	Support ring for tensioning system
	1B	Valves and actuators
	II	Inflection restrictors
2.2 Flexible	1A	Flexible riser
	1A	Connectors
	1B	Buoyancy elements
3. Riser tensioning system	1B	Riser compensator
	1B	Hydro-pneumatic accumulator
	1B	Pressure vessel
	1B	Pipe system
	II	Wire ropes
	II	Sheaves
	1B	Telescopic arm for wire ropes
	II	Control panel
	II	Air compressor with drier
4. Hoisting and handling equipment for rigid riser	1A	Derrick
	1A	Crown block with supporting beams
	1A	Travelling block
	1B	Hook
	II	Wire ropes
	1B	Air tuggers for personnel
	II	Air tuggers
	1B	Loose equipment for riser handling
	1A	Crane for handling production equipment
5. Oil production/processing equipment	1B	Production manifold with valves
	1B	Separator
	1B	Heat exchanger
	1B	Gas liquid separator/cleansers
	1B	Gas compressor (pressure side)
	1B	Dehydrators
	1B	Crude oil loading pumps
	1B	Crude oil and gas metering equipment
	1B	Gas liquid separator tanks
	1B	Glycol contactor
	II	Water injection pump (pressure side)
	1B	Glycol injection pump with equipment
	1B	Oil protection and process shut-down equipment
	1B	Valves and pipes
	1A	Flare system
	1B	Pig launcher/receiver unit
	II	Instrumentation and control equipment
	1A	Swivel for production
6. Pressure vessels (general)	1B	Pressure vessels
7. Miscellaneous equipment	1A	Flare booms
	1B	Burners
	II	Instrumentation components in general
8. For well overhaul and maintenance equipment, *see* Table A2.1.	1B	Main instrumentation components and equipment in critical systems (e.g., control panels)

NOTES
1. The equipment list is intended as a guide only and does not necessarily cover all the equipment items found in a production plant facility.
2. Equipment considered to be important for safety which is not listed in the table will be specially considered by LR and categorised.

Section B1
Survey requirements

B1.1 Application

B1.1.1 The information in this Appendix is intended to provide guidance to Owners and Surveyors for the inspection of classed positional mooring systems as defined in Chapter 10.

B1.2 Annual Surveys

B1.2.1 Annual Surveys are to be carried out in accordance with Pt 1, Ch 3 with the vessel at its normal operational draft with the positional mooring system in use.

B1.2.2 The purpose of the Annual Survey is to confirm that the mooring system will continue to carry out its intended purpose until the next Annual Survey. No disruption of the unit's operation is intended. Where practicable the Annual Survey is to be carried out during a relocation move.

B1.2.3 The scope of the Annual Survey is limited to the mooring components adjacent to winches, windlasses and fairleads. Depending on the mooring component visible from the unit, particular attention should be given to:

(a) Chain:
- Wear in the chain shoulders in way of the chain stopper, windlass pockets and fairleads.
- Support of chain links in the windlass pockets.

(b) Wire rope:
- Flattened ropes.
- Broken wire.
- Worn or corroded ropes.

B1.2.4 The Surveyor should examine the maintenance records and determine if any problems have been experienced with the mooring system in the previous twelve months, e.g., breaks, mechanical damage, loose joining shackles, and chain or wire jumping.

B1.2.5 Should the Annual Survey reveal severe damage or neglect to the visible chain or cable, a more extensive survey will be required by Lloyd's Register (hereinafter referred to as 'LR').

B1.2.6 Typical damage warranting a more comprehensive survey would include:

(a) Chain:
- Reduction in diameter exceeding 75 per cent of the margin assumed in the design, *see* Ch 10,8.2.
- Missing studs.
- Loose studs in Grade 4 chain.
- Worn lifters (i.e., gypsies) causing damage to the chain.

(b) Wire rope:
- Obvious flattening or reduction in area.
- Worn cable lifters causing damage to the wire rope.
- Severe wear or corrosion.

B1.3 Special Surveys

B1.3.1 Special Periodical Surveys are to be carried out at five-yearly intervals in accordance with Pt 1, Ch 3, and will require extensive inspection, usually associated with a sheltered water visit. When considered necessary by LR the interval between Special Periodical Surveys may be reduced.

B1.3.2 The purpose of the Special Survey is to ensure that each anchor line is capable of performing its intended purpose until the next Special Survey, assuming that appropriate care and maintenance is performed in the mooring system during the intervening period.

B1.3.3 The Special Survey should include:

(a) Close visual inspection (100 per cent) of mooring chains, with cleaning as required.
(b) Enhanced representative NDT sampling.
(c) Dimension checks.

B1.3.4 Particular attention is to be given to the following:
- Cable or chain in contact with fairleads, etc.
- Cable or chain in way of winches, windlass and stoppers.
- Cable or chain in way of the splash zone.
- Cable or chain in the contact zone of the sea bed.
- Damage to mooring system.
- Extent of marine growth.
- Condition and performance of corrosion protection.

B1.3.5 This survey is to ensure that the lengths of anchor line frequently in contact with winches, windlasses and fairleads are suitably rated for this application.

B1.3.6 Joining shackles are to be examined for looseness and pin securing arrangements. All joining shackles of the Kenter type and bolted type which have been in service for more than four years should be dismantled and an MPI performed on all machined surfaces as per B2.6.3.

B1.3.7 Visual surveys of all windlass and fairlead chain pockets are to be carried out with particular attention to the following:
- Unusual wear or damage to pockets.
- Rate of wear on pockets including relative rate of wear between links and pockets.
- Mismatch between links and pockets, and improper support of the links in the pockets.

B1.3.8 The thickness (diameter) of approximately one per cent of all chain links should be measured. The selected links should be approximately uniformly distributed through the working length of the chain. The above percentage may be increased/decreased if the visual examination indicates excessive/minimal deterioration.

B1.3.9 A functional test of the mooring system during anchor-handling operation is to be carried out with particular attention given to the following:

- Smooth passageway of chain links and or/wire rope and joining shackles over the windlass and fairleads pockets.
- The absence of chain jumping or other irregularities.

B1.4 Special Continuous Surveys

B1.4.1 As an alternative to the Special Survey, the Owner may agree with LR that the Special Survey may be carried out on a continuous survey basis by providing an extra mooring line which may be regularly inspected on shore and exchanged with lines installed on the unit in accordance with an appropriate schedule.

■ *Section B2*
General guidelines on inspection of mooring system components

B2.1 Anchor inspection

B2.1.1 The anchor head, flukes and shank are to be examined for damage, including cracks or bending. The anchor shackle pin should be examined and renewed if excessively worn or bent. Moveable flukes should be free to rotate.

B2.1.2 Bent flakes or shank should be heated and jacked in place according to an approved procedure, followed by Magnetic Particle Inspection.

B2.2 Anchor swivels

B2.2.1 Although swivels are no longer in common use, anchors have been lost due to corrosion of the threads engaging the swivel nut. Swivel nut threads should be carefully examined and if significant corrosion is found, the swivel should be removed or replaced.

B2.3 Chain inspection criteria

B2.3.1 This sub-Section applies only to ‘Offshore’ or ‘Rig Quality’ chains with studs secured by one of the following means:

- Mechanically locked in way of the link's flash-butt weld and fillet welded on other end (IACS R3 chain for example); or
- Studs mechanically locked in place on both ends (IACS R4 chain for example).

Other types of chain will require special consideration.

B2.3.2 The service environment of offshore mooring chain is more severe than the service environment for conventional ship anchoring chain. Offshore chain is exposed to service loads for a much longer period of time. The long-term exposure to cyclic loadings in sea-water magnifies the detrimental effect of geometric and metallurgical imperfections on fatigue life. Moreover, the increased number of links in offshore chains renders the chain more susceptible to failure from a statistical standpoint.

B2.3.3 Due to the effect of notches, e.g., the stud footprint, higher strength steels such as that used for IACS R4 chain have a lower ratio of fatigue strength to static tensile strength than typical lower strength steel such as used for IACS R3 chain.

B2.3.4 Since chain link diameter loss can be due to abrasion and corrosion, diameter measurements should be taken in the curved or bend region of the link and any area with excessive wear or gouging. Two diameter measurements should be taken 90 degrees apart. Particular attention should be given to the shoulder areas which normally contact the windlass or fairlead pockets.

Links should be rejected if the minimum cross-sectional area is less than the minimum Rule chain size plus a margin for corrosion and wear between surveys, *see* Ch 10,8.2. If repair is permitted it should be done by qualified personnel using an approved procedure.

NOTE
WELD REPAIR IS NOT PERMITTED ON IACS R4 CHAIN (*see* B2.3.6).

Two diameter measurements should be taken 90 degrees apart.

B2.3.5 Since studs prevent knots or twist problems during chain handling and support the sides of the links under load to reduce stretching and bending stresses, missing studs are not acceptable. Links with missing studs should be removed or the studs should be refitted using an approved procedure.

B2.3.6 Where chain studs are secured by fillet welds on one end, the stud is likely to fall out if a stud is loose or the weld is cracked. Any axial or lateral movement is unacceptable and the link must be repaired or replaced.

Links with studs fillet welded on the flash-butt weld end of the stud are unacceptable.

Rejection of links with gaps exceeding 3 mm between the stud and the link at the flash-butt weld end of the stud should be considered. Closing the gap by renewing the fillet weld may be considered but *see* the note in B2.3.8.

B2.3.7 Field repair of cracked welds should be avoided if at all possible. Welding must be performed by qualified personnel using approved procedures:

NOTE

WELD REPAIR IS NOT PERMITTED IN IACS R4 CHAIN.

Chains with studs mechanically locked in place on both ends may only be repaired by an approved mechanical squeezing procedure to reseat the stud.

B2.3.8 Fillet welding of studs in both ends is not acceptable; nor is welding on the stud end adjacent to the link's flash-butt weld.

Existing studs with fillet welds on both ends will require special consideration and will be subject to special crack detection methods. A reduction in mechanical properties in way of the flash-butt weld will normally be required.

B2.3.9 Where chain studs are secured by press-fitting and mechanical locking, it is very difficult to quantify excessive looseness of chain studs. The decision to reject or accept a link with a loose stud must depend on the Surveyor's judgement of the overall condition of the chain complement.

Axial movement of studs of 1 mm or less is acceptable. Links with axial movement greater than 2 mm must be replaced by squeezing or removed. Acceptance of chain links with axial movements from 1 to 2 mm must be evaluated based on the environmental conditions of the unit's location and expected period of time before the chain is again available for inspection.

Lateral movement of studs up to 4 mm is acceptable.

B2.3.10 Where links are damaged and have cracks, gouges and other surface defects (excluding weld cracks), they may be removed by grinding, provided B2.3.4 is complied with.

Links with surface defects which cannot be removed by grinding should be replaced.

Where defective links are found, they are to be removed and replaced with joining shackles, i.e., connecting links guided by the following good marine practice:

(a) The replacement joining shackle is to comply with IACS W22 or API 2F.
(b) Joining shackles are to pass through fairleads and windlasses in the horizontal plane.
(c) Since joining shackles have much lower fatigue lives than ordinary chain links, as few as possible should be used. On average, joining shackles should be separated by 120 metres or more.
(d) If a large number of links meet the discard criteria and these links are distributed in the whole chain length, the chain should be replaced with new chain.

B2.4 Fairlead and windlass inspection – Chain system

B2.4.1 Fairlead inspections should verify that all fairleads move freely about their respective pivot axes, to the full range of motion required for their proper operation. All bolts, nuts and other hardware used to secure the fairlead shafts should be inspected and replaced as required.

Fairlead attachment to the hull should be verified and NDT conducted as necessary.

NOTE

There have been cases of closing plates on the fairlead shaft coming loose due to corrosion of the threads of the securing bolts, resulting in serious damage to the fairlead arrangements and the complete jamming of the fairlead and chain. Consequently, the securing bolts should also be checked to ensure that the bolt material does not corrode preferentially should the sacrificial anode system fail to function in way of the fairlead.

B2.4.2 Special attention should be given to the holding ability of the windlasses. The chain stopper and the resultant load path to the unit's structure should be inspected and its soundness verified.

B2.4.3 It is essential that a link resting in a chain pocket makes contact with the fairlead at only the four shoulder areas of the link to avoid critical bending stresses in the link. Satisfactory chain support is to be verified, and excessive wear in the pockets should be repaired as required to prevent future damage to the chain.

B2.4.4 Chain pockets may be repaired by welding in accordance with the standard procedures supplied by the fairlead/windlass manufacturer. Normally, the hardness of the pockets should be slightly softer than the hardness of the chain link and procedures must be specific for the chain quality used.

B2.5 Fairleads and windlass – Wire rope systems

B2.5.1 Fairleads are to be inspected in accordance with B2.4.1.

B2.5.2 Special attention should be given to the holding ability of the winch and the satisfactory operation of the pawls, ratchets and braking equipment. The soundness of the resultant load path to the unit's structure should be verified.

Proper laying down of the wire on the winch drum should be verified to the satisfaction of the Surveyor and drums and spooling gear adjustments made if required.

B2.6 Inspection of miscellaneous fittings

B2.6.1 Anchor shackles, large open links, swivels and connecting links should be visually inspected. Certain areas should be examined by MPI. Areas to be examined should be clearly marked on each item. Links and fittings should be dismantled as required. Damaged items should be replaced as required by the attending Surveyor. Illustrations showing the areas of concern may be found in API RP 2I, Figure 7. General guidance on the areas requiring MPI is listed as follows:

- Large open links: the interior contact surfaces of large open links.
- Bolted shackles: the inside contact areas and the pins.
- Swivels: the swivel pin and threads and mating surface.

B2.6.2 Experience has shown that large numbers of anchors and chains are lost in service due to connecting link failure. Fatigue problems have resulted from poorly designed machined faces and corners. Joining shackles of Kenter or similar designs manufactured before 1984 are of particular concern. Joining shackles used for higher strength chains, such as ORQ and above, which do not have certificates of equivalent quality should be rejected.

B2.6.3 All joining shackles of Kenter or similar design which have been in service for more than four years should be dismantled and MPI carried out. Illustrations showing the areas of concern may be found in API RP 2I, Figure 7. General guidance in the areas requiring MPI is listed as follows:

- Joining-shackle links: all machined and ground services of the link and the sides of the curved portions of the link.
- Joining-shackle stud: machined surfaces only.
- Joining-shackle pin: 100 per cent.

Fatigue is considered to be the critical criterion in way of the machined surfaces. On the remaining surface, the profile should be ground smooth and MPI should be carried out upon completion of grinding. In general, the radius of the completed grinding operation should produce a recess with a minimum radius of 20 mm and a length along the link bar greater or equal to six times its depth.

NOTE

Sandblasting prior to MPI may change the machined surfaces and should be avoided. Alternative methods of cleaning should be used.

Where links are damaged and have cracks, gouges or other surface defects (excluding weld cracks), they may be removed by grinding, provided B2.3.4 is complied with.

Links with surface defects which cannot be removed by grinding should be replaced.

Where defective links are found, they are to be removed and replaced with joining shackles, i.e., connecting links guided by the following good marine practice:

(a) The replacement joining shackle is to comply with IACS W22 or API 2F.
(b) Joining shackles are to pass through fairleads and windlasses in the horizontal plane.
(c) Since joining shackles have much lower fatigue lives than ordinary chain links as few as possible should be used. On average, joining shackles should be separated by 120 metres or more.
(d) If a large number of links meet the discard criteria and these links are distributed in the whole chain length, the chain should be replaced with new chain.

B2.6.4 Tapered pins holding the covers of connecting links together should make good contact at both ends and the recess of counterbore at the large end of the pin holder should be solidly plugged with a peened lead slug to prevent the pin from working out.

B2.6.5 Any joining shackles of Kenter or similar designs which are loose upon reassembly should be rejected.

B2.7 Wire rope

B2.7.1 Acceptance criteria should be guided by ISO-Standard 4309-1981(E). Further insight may be gained from the discard guidance provided by API RP 2I, Figures 18 and 19.

B2.7.2 It should be borne in mind that ISO-Standard 4309-1981(E) is primarily intended for lifting appliances where the Factor of Safety may be higher than for mooring wires.

B2.7.3 The Surveyor should exercise great care in his interpretation of the condition of the wire. An obvious acceptance or rejection is comparatively easy, but the grey area between is difficult to evaluate. The Surveyor must make a sound evaluation and technical judgement based on all available evidence.

B2.7.4 In general, the age or time in service of the wire does not directly have a bearing on the acceptance or rejection of the wire other than as a factor to be taken into consideration by the Surveyor when deciding on the extent of the survey.

B2.7.5 100 per cent visual examination of wire ropes is to be carried out and diameter measurements should be performed.

B2.7.6 Visual examination should identify and record the following items for each steel wire anchor line:

(a) The nature and number of wire breaks:
    - Wire breaks at the termination.
    - External wear and corrosion.
    - Localised grouping of wire breaks.
(b) Deformation:
    - Fracture of strands.
    - Termination area.
    - Reduction of rope diameter, including breaking or extrusion of the core.

B2.7.7 Diameter measurements should be taken at approximately 110 metre intervals, at the discretion of the attending Surveyor. If areas of special interest are found, the survey may be concentrated on these areas and diameter measurements taken at much smaller intervals.

B2.7.8 An internal examination should be undertaken as far as practicable if there are indications of severe internal corrosion or possible breakage of the core or wire breaks in underlying areas. *See* API RP 2I, Section 2.3.6.3, for guidance on the internal inspection of wire rope.

B2.8 Guidance on wire rope damage

B2.8.1 The cause of wire rope failures may be deduced from the observed damage to the rope. The information summarised in this sub-Section covers most types of wire rope failure. More detailed information, including photographic examples, is available in ISO-Standard 4309-1981(E) and API RP 2I.

B2.8.2 Broken wires at the termination indicate high stresses at the termination and may be caused by incorrect fitting of the termination, fatigue, overloading, or mishandling during deployment or retrieval.

(a) Distributed broken wires, illustrated by Figures 9 to 12 of API RP 2I, may indicate the reason for their failure:
- Crown breaks or breakage of individual wire at the top of strands may be caused by excessive tension, fatigue, wear or corrosion.
- Excessive tension is indicated by necking down of the broken end of the wire.
- Fatigue is indicated by broken faces perpendicular to the axis of the wire.
- Corrosion and wear may be indicated by reduced cross-sections of the wire.
- Valley breaks at the interface between two strands indicate tightening of the strands, usually caused by a broken core or internal corrosion which has reduced the diameter of the core.
- Valley breaks can be caused by high loads, tight sheaves of too small a diameter.

(b) Locally grouped broken wires in a single strand or adjacent strand may be due to local damage. Once begun, this type of damage will usually get worse.

B2.8.3 Changes in rope diameter can be caused by external wear, interwire and interstrand wear, stretching or corrosion. A localised reduction in rope diameter may indicate a break in the core. Conversely, an increase in rope diameter may indicate a swollen core due to corrosion.

B2.8.4 Wear on the crown of outer strands in the rope may be caused by rubbing against fairleads, unit structure or the sea bed, depending on the location of the wear. Internal wear between individual strands and wires in the rope is caused by friction and is accelerated by bending of the rope and corrosion.

B2.8.5 Corrosion decreases rope strength by reducing the cross-sectional area and accelerates fatigue by creating an irregular surface which invites stress cracking. Corrosion is indicated by:

(a) The diameter of the rope at fairleads will grow smaller.

(b) The diameter of stationary ropes may actually grow larger, due to rust under the outer continuous layer of strands. Diameter growth is rare for mooring lines.

B2.8.6 Deformation, i.e., distortion of the rope from its normal construction, may result in an uneven stress distribution in the rope. Kinking, bending, scrubbing, crushing, and flattening are common wire rope deformations. Ropes with slight deformations will not lose significant strength. Severe distortions can accelerate deterioration and lead to premature failure.

B2.8.7 Thermal damage, although rare for mooring ropes in normal service, may be indicated by discoloration. Prompt attention should be given to damage caused by excessively high or low temperatures. The effect of very low temperatures on wire rope is unclear except for the known detrimental effect on lubricants.

■ *Cross-references*

Wire rope
API RP 2I and ISO-Standard 4309-1981(E)
(Please note comment in B2.7.2 regarding the ISO-Standard)

Chain
API RP 2I '*Recommended Practise for In-service Inspection of Mooring Hardware for Floating Drilling Units*'.

Section C1 Introduction

C1.1 Application

C1.1.1 This document has been extracted from standard LR Group Oil and Gas project Verification Work Instructions, for issue as part of the LR Quality System and should be read in conjunction with Project-Specific Quality Plan and supporting procedures. It is intended to outline appropriate scopes of survey for typical safety critical items of equipment associated with disconnectable or mobile drilling and production installations where LR is providing Certification or Verification/Validation services. The list is not exhaustive and should be used as a guide for equipment which is to be included within the scope of the service to be provided. The extent to which the Surveyors are required to attend in order to ensure that each item of equipment complies with a recognised Code, specification, or agreed Standard of performance is to be agreed with LR. The attendance required will be indicated on the supplier's Inspection and Test plan as a minimum. The procedures between Project Vendors and their local LR Surveyors are to be agreed.

C1.1.2 Some typical acceptable Codes and Standards are referenced herein. Other National or International Standards may be considered and accepted if deemed appropriate by LR. Company standards may also be applied where they represent an agreed standard of performance. *See also* Appendix A, Section 1.

C1.1.3 Where equipment is identified as being safety critical to an installation, survey/examinations undertaken within their examination schemes or codes may be considered to contribute to the validation required of such equipment. Safety critical equipment/elements are those such parts of an installation and such parts of its plant (including computer programs), or any part thereof;

(a) The failure of which could cause or contribute substantially to; or
(b) A purpose of which is to prevent, or limit the effect of, a major accident.

Section C2 Scope of survey for equipment

C2.1 Accommodation/temporary refuge units

C2.1.1 Design appraisal and survey of structure, pipework, HVAC arrangements, and fire and overpressure protection is required. *See also* C2.37 and C2.41.

C2.2 Accumulators

C2.2.1 *See* C2.29.

C2.3 Air receiver and drier vessels

C2.3.1 Where the maximum air pressure is equal to 7 barg (100 psi) or greater, a survey to Code requirements including design appraisal is required.

C2.3.2 Where the pressures are less than 100 psi, valid manufacturers' documentation can be accepted. Material is to be manufactured to a recognised pressure vessel standard.

C2.3.3 Typical acceptable standards: BS 5169, ASME VIII Div. 1 and BS 5500.

C2.4 Air winches

C2.4.1 *See* C2.33.

C2.5 Blast rated boundaries/enclosures

C2.5.1 Design appraisal for rated blast overpressure and construction under survey is required.

C2.6 Blow out preventers and BOP control unit

C2.6.1 *See* C2.57.

C2.7 Burner (flare) booms or towers

C2.7.1 Design appraisal is required with respect to:

(a) Environmental loads.
(b) Loads onto platform unit.
(c) Location and length with respect to heat radiation hazard.
(d) Construction under survey.

C2.7.2 Typical acceptable Standards are Structural Design A.I.S.C., Fabrication AWS D1.1, BS 4870, BS 4871 and Heat Radiation API RP 521.

C2.8 Coolers/chillers

C2.8.1 *See* C2.25.

C2.9 Compressors/compressor packages

C2.9.1 Reciprocating machines above 100 kW are to be built under survey with design appraisal of piping systems, any contained pressure vessels and torsional vibration characteristics for large reciprocating machines. Hydrostatic tests to be witnessed and manufacturers' data examined for other components. *See also* C2.53 and C2.55.

C2.10 Cranes

C2.10.1 *See* C2.33.

C2.11 Deluge systems

C2.11.1 Review of P&IDs, hydraulic calculations, area coverage and pump capacities is required. For survey, *see* C2.12, C2.41 and C2.45.

C2.12 Diesel prime movers

C2.12.1 For air compressors, mud pumps, cement pumps, generators and drawworks except fire.

C2.12.2 Pumps and emergency generators.

C2.12.3 Design appraisal with respect to vibration (i.e., hazardous areas), torsional vibration characteristics of shaft system and witness of commissioning of machines is required.

C2.12.4 For fire pumps, vessel propulsion, auxiliary service and emergency generators.

C2.12.5 Survey is required where the power is equal to or in excess of 100kW and to include above. If power is less than 100kW, manufacturers' documentation can be accepted. Engines should be suitably marinised, batch and line approved and able to operate under the conditions specified in LR Rules.

C2.13 Distillation plants

C2.13.1 *See* C2.25.

C2.14 Drums

C2.14.1 *See* C2.43.

C2.15 Electrical equipment

C2.15.1 Survey at manufacturers' works is not required for equipment that is not specified in LR Classification Rules requirements. Equipment must be manufactured in accordance with a recognised Standard and manufacturers' certificates are required. Flameproof and I.S. equipment is to be supplied with relevant certification and documentation issued by a recognised authority and must be suitable for the application. After installation under survey, the integrity of the complete system is to be established.

C2.16 Emergency shut-down systems/fire and gas systems

C2.16.1 Witness of testing and documentation review at suppliers' works by a specialist LR Surveyor is recommended (mandatory where full Cause and Effect Testing is not repeated during the installation commissioning phase).

C2.16.2 Design appraisal requirements will vary according to the responsibilities assigned to the supplier by the main design contractor. For programmable systems, details of Hardware, system specification and Software QA manuals will be required for review. (Process control systems do not require LR survey at suppliers' works).

C2.17 Fans

C2.17.1 Survey at manufacturers' works is not required. Manufacturers' documentation to be supplied.

C2.17.2 When intended for use in hazardous areas, fans must be of non-sparking type.

C2.18 Filters

C2.18.1 *See* C2.43.

C2.19 Fire and foam pumps

C2.19.1 *See* C2.12.

C2.20 Flare booms and towers

C2.20.1 *See* C2.7.

C2.21 Flexible hoses

C2.21.1 Manufacturers' documentation, including prototype burst testing is required. Fire test certification is generally required for hydrocarbons, high pressure and essential control service.

C2.22 Fluid transfer systems (fluid swivel type)

C2.22.1 Strength design appraisal and survey during manufacture, assembly and test is required.

C2.23 Gas turbines/compressors

C2.23.1 *See* C2.53.

C2.24 Geared machinery

C2.24.1 Witness of commissioning and testing after installation is required.

C2.25 Heat exchangers

C2.25.1 **Hydrocarbons**. Design appraisal and survey during manufacture to Code requirements is required.

C2.25.2 **Non-hydrocarbons**, Design pressures greater than or equal to 7 barg (100 psi). Design appraisal and survey during fabrication is required. *See also* C2.43, which applies equally to shell and tube exchangers.

C2.25.3 **Non-hydrocarbons**. Design pressures less than 7 barg (100 psi). Manufacturers' documentation can be accepted with hydrostatic tests being witnessed after installation. Material is to be manufactured to a recognised pressure vessel standard.

C2.25.4 Typical acceptable codes: PD 5500, ASME VIII Div. 1 & 2 and TEMA Standards.

C2.26 Helideck

C2.26.1 Design appraisal of structure, markings, lights, obstacle free/drop off zones, fire and escape arrangements is required. Survey under fabrication as for modules.

C2.27 Hoists

C2.27.1 *See* C2.33.

C2.28 Hydrocyclones

C2.28.1 Survey at manufacturers' works is not required for proprietary drilling equipment.

C2.28.2 *See* C2.43.

C2.29 Hydro-pneumatic accumulators – Manifolds, fluid reservoirs

C2.29.1 Design appraisal and construction under survey is required.

C2.29.2 Typical acceptable standards: BS 5045 and ASME VIII Div. 1.

C2.30 Impressed current CP system

C2.30.1 Design appraisal. Survey of installation, witness test and commissioning are required.

C2.31 Inert gas generator

C2.31.1 Design appraisal and survey at manufacturers' works. Witness test and commissioning are required.

C2.32 Lifeboats, TEMPSCs, rescue craft and davits

C2.32.1 Design appraisal and survey at manufacturers' works. Witness test and commissioning are required.

C2.33 Lifting appliances and cranes

C2.33.1 To be built under survey in accordance with the LR's Code for Lifting Appliances in a Marine Environment, which would include design appraisal, material identification, weld procedures and welder qualification tests, approval of NDT procedures and testing on completion. Care is to be taken that the appliance is suitable for use under dynamic loading offshore.

C2.33.2 Air winches (non-personnel). No survey required at source. Manufacturers' documentation will be accepted provided it includes evidence of hydrostatic test of pressure parts.

C2.33.3 Cranes mountings, including pedestals. Design appraisal and construction under survey is required. Witness of testing and commissioning after installation is also required.

C2.33.4 Other typical acceptable construction codes are given in Appendix A1.2.13.

C2.33.5 Personnel hoist. Design appraisal and construction under survey is required. Witness of testing and commissioning after installation is also required.

C2.33.6 Other lifting devices. Where LR Certification is required by the client, design appraisal and survey with load testing after installation on the platform/unit is required.

C2.33.7 Other lifting devices. Where LR Certification is not required, inspection and testing at the manufacturers' works is required only for devices with a capacity greater than or equal to 10 tonnes. Devices with a capacity of less than 10 tonnes can be accepted if presented with valid manufacturers' documentation. In addition, they must be tested after installation.

C2.34 Loading instrument

C2.34.1 To be verified for LR Classification compliance – *see* Part 1. Hardware to be type approved for marine use.

C2.35 Manifolds, choke, production, test, etc.

C2.35.1 Design appraisal and survey is required.

C2.35.2 Typical acceptable standards: ANSI B3 1.3.

C2.36 Metering packages and equipment

C2.36.1 To be built under survey with design appraisal of piping systems aspects and any pressure vessels. Hydrostatic test to be witnessed and manufacturers' data examined for all other aspects.

C2.37 Modules (all types)

C2.37.1 Design appraisal and survey of structure during construction is required and the following loads should be considered in the design.
(a) Environmental.
(b) Equipment and operational weights.
(c) Construction, including lifting case.

C2.37.2 *See also* C2.41.

C2.38 Mooring systems (floating installations)

C2.38.1 Structural. Design appraisal and survey during manufacture is required for all components, including anchors, cables, chains, turret structure, etc.

C2.38.2 Machinery. Design appraisal is required for all main bearings, mooring winches and chain stoppers.
NOTE:
Quayside mooring equipment can be accepted on the basis of manufacturers' documentation.

C2.39 Offloading systems

C2.39.1 *See* C2.21, C2.41 and C2.46.

C2.39.2 Strength design appraisal of mooring winches, breakaway couplings, etc., is required.

C2.40 Pig launchers and receivers

C2.40.1 *See* C2.43.

C2.41 Pipework and fittings

C2.41.1 All fabricated pipework, e.g., process systems, gas and liquid fuel systems, fire main, compressed air lines, hydraulic systems, mud systems, etc., will be subject to design appraisal and survey during fabrication. Pipe fittings will normally be accepted with manufacturers' documentation, but significant fabricated items may require survey at manufacturers' works. Fabricated saddles for use in the fire main should be supplied with a copy of a valid proof test certificate.

C2.41.2 The survey must include:
(a) Review of QA/QC system.
(b) Examination at works during fabrication and test.
(c) Review and acceptance of weld procedures and welder qualification tests.
(d) Review and acceptance of NDT procedures.
(e) Verification of materials against relevant mill certificates.
(f) Appraisal of P&IDs, material and pipe schedules.

C2.41.3 Where pipework is included as part of a package, it is to be surveyed as above.

C2.41.4 Typical acceptable standards: ANSI B3 1.3.

C2.42 PLCs/programmable electronic systems

C2.42.1 Hardware to be type approved for offshore use. Software to be developed under suitable software QA system. LR to witness commissioning tests.

C2.43 Pressure vessels

C2.43.1 (Separators, knockout drums, pulsation dampers, etc., including auto sprinkler and fire-extinguishing storage systems).

C2.43.2 Where the system gauge pressure in bar multiplied by the internal volume in litres exceeds 200, vessels are to be built under survey which would include design appraisal, material identification, weld procedure and welder qualification tests and approval of NDT procedures. The vessel is to be built in accordance with a recognised Code or Standard and subject to hydrostatic test and internal examination on completion.

C2.43.3 Typical acceptable codes: PD 5500 and ASME VIII.

C2.44 Process equipment (bulk)

C2.44.1 All equipment, whether installed initially or at a subsequent date, should be manufactured to a relevant Code, Standard or specification and written confirmation of this, together with appropriate test certificates, should be obtained from the manufacturer. *See* C2.41 and the remainder of this appendix for individual equipment items.

C2.45 Pumps – Fire, water deluge, foam, etc.

C2.45.1 All fire-fighting pumps (and prime movers) to be built under survey.

C2.45.2 Material certificates and certificates for hydrostatic testing of cast casings, etc., to be reviewed.

C2.46 Pumps for other services

C2.46.1 Survey at manufacturers' works for verification purposes is not required. Manufacturers' documentation including material certificates is to be supplied.

C2.47 Radio tower

C2.47.1 Design appraisal will be required only in respect of:
(a) Environmental loads.
(b) Loads transmitted to the structure.
(c) Location relating to the helideck.

C2.47.2 No fabrication inspection is required.

C2.48 Regenerators and absorbers, glycol – (fired) boilers and steam receivers – (fired)

C2.48.1 Design appraisal and survey is required – *see also* C2.43 and C2.25.

C2.49 Separators

C2.49.1 *See* C2.43.

C2.50 Steel – plate, rolled sectors, tubulars and pipe

C2.50.1 For certification, inspection/validation at mill in accordance with a recognised Standard and specification is required on all material for primary structures. However, certification of other IACS members will in general be acceptable.
(a) Jackets including conductor framing.
(b) Piles.
(c) Any secondary steel that is connected directly to the primary structure.
(d) Any structural steel utilised for the load-bearing frame-work of the module.
(e) Where floors contribute to the strength and integrity of the module. Where steel is procured from steelworks approved by LR, our scope will normally be limited to witness of mechanical testing and check of results against agreed specifications. In the event of primary steel being procured from stockists, LR involvement will normally consist of verification of test certificates, material identification and confirmation of properties against agreed specifications.

C2.50.2 Materials for secondary structures need not be inspected at source provided the material is manufactured in accordance with a recognised Standard and is supported by manufacturers' valid mill certificates.

C2.50.3 Examples of secondary structures include gangways, walkways, handrails, cladding, helideck, floors, pipe supports, equipment plinths, mud and similar tanks and installation aids.

C2.51 Strainers

C2.51.1 *See* C2.43.

C2.52 Tanks

C2.52.1 Dry mud, barytes, bulk cement, chemicals:
(a) Design appraisal and survey is required if the above tanks are to be subjected to any positive or negative pressure conditions.
(b) If not pressurised, the Surveyors may accept a Third Party Inspection Certificate with evidence of testing for the purpose intended.

C2.52.2 Non hazardous liquid storage tanks – Open, vented or hydrostatic head only. Third party Inspection Certificate with evidence of construction and testing to a recognised Code or specification is required.

C2.52.3 Pressurised lubricating oil or seal-oil tanks. Design appraisal and survey is required.

C2.52.4 Fuel tanks and hazardous liquid tanks. Design appraisal and survey is required. Typical acceptable standards: BS 799 part IV and BS 2654.

C2.53 Turbines and compressors

C2.53.1 Design pressure greater than or equal to 7 barg (100 psi). Surveyor is to verify manufacturers' documentation, witness hydraulic tests of pressure parts and commissioning of machines.

C2.53.2 Design pressure less than 7 barg (100 psi). Surveyor is to verify manufacturers' documents and witness commissioning. Material is to be manufactured to a recognised pressure vessel standard.

C2.53.3 Gas turbines. Consideration should be given to the codes used for pressure-retaining components and the need for containment, with a view to minimising and localising damage in the event of rotor blade failure. Survey of fabricated pressure-retaining items will generally be required.

C2.54 Umbilicals for subsea completion control systems

C2.54.1 Design appraisal and survey at source to include review of manufacturing and quality plans is required. Witness of factory acceptance tests and documentation review is also required.

C2.55 Valves including emergency shut-down and safety valves

C2.55.1 In general, valves and fittings need not be surveyed at source provided they are manufactured in accordance with a recognised Code or Standard and are identifiable with a manufacturers' certificate which includes the materials used for pressure-containing parts.

C2.55.2 Details of certain large valves and fittings of welded construction will require to be submitted for special consideration, (e.g., Riser ESDVs, SSIVs, etc.). Design appraisal and survey of these items will be required in most cases.

C2.55.3 Testing of pressure relief valves to be witnessed during commissioning at fabrication sites.

C2.55.4 Typical acceptable standards: Safety Valve Design API RP 520, Valves API 6 series, B55351 and Fittings BS 1640.

C2.56 Ventilation and pressurisation systems including fire dampers

C2.56.1 Design appraisal: hazardous area zones and structural fire protection. The systems are to be surveyed and tested during installation and commissioning.

C2.56.2 Fire Dampers are to be type approved.

C2.57 Well control equipment

C2.57.1 Independent Review Certificate from a Certifying Authority is to be issued for manufacture and design. Surveyors will issue a Certificate of Conformity following completion of the equipment and when satisfied that the equipment has been built and tested in accordance with the approved Specification for Manufacture. Manufacturers' records of materials, inspection and tests should be assessed by the Surveyor.

C2.57.2 For Verification (Wells Examination). Well control equipment will be subject to a design examination and survey during construction/assembly and testing where the equipment is designated as safety critical to the Installation.

C2.57.3 Work done by others to meet the requirements of the well examination scheme will contribute to verification.

C2.58 Well control panel

C2.58.1 Design appraisal and survey, as for pipework and fittings.

C2.59 Winches

C2.59.1 *See* C2.33.

C2.60 Xmas trees

C2.60.1 *See* C2.58.

Rules and Regulations for the Classification of Mobile Offshore Units

Part 4
Steel Unit Structures

June 2013

LIFE MATTERS

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■ *Section 1* Rule application

1.1 General

1.1.1 The Rules, in general, apply to steel units of all welded construction. The use of other materials in the structure will be specially considered. The Rules apply to the unit types defined in Parts 1 and 3. Units of unconventional design will receive individual consideration based on the general standards of the Rules.

1.2 Loading

1.2.1 The Rules are framed on the understanding that units will be properly loaded and operated. Units are to be operated in accordance with an Operations Manual which is to contain all the necessary information for the safe loading and operation of the unit, *see* Pt 3, Ch 1,3.

1.2.2 For surface type units, loading guidance information may be required by means of a Loading Manual, *see* Pt 1, Ch 2,1.1.9. The loading manual may be a separate document or the information can be included in the Operations Manual.

1.2.3 Where an onboard computer system having a longitudinal strength or a stability computation capability is provided, the system is to be certified in accordance with LR's *Approval of Longitudinal Strength and Stability Calculation Programs*.

1.3 Advisory services

1.3.1 The Rules do not cover certain technical characteristics such as stability, trim, vibration, docking arrangements, etc. The Classification Committee cannot assume responsibility for these matters, but is willing to advise upon them on request.

1.4 Intact and damage stability

1.4.1 New units will be assigned class only after it has been demonstrated that the level of intact and damage stability is adequate, *see* Pt 1, Ch 2,1.

1.4.2 For classification purposes, the minimum requirements for watertight and weathertight integrity are to comply with Chapter 7.

■ *Section 2* Direct calculations

2.1 General

2.1.1 Direct calculations may be specifically required by the Rules or may be submitted in support of alternative arrangements and scantlings. LR may undertake independent calculations to check the calculations submitted by the designers.

2.2 Equivalents

2.2.1 In addition to cases where direct calculations are specifically required by the Rules, LR will consider alternative arrangements and scantlings which have been derived by direct calculations in lieu of specific Rule requirements. All direct calculations are to be submitted for examination.

2.2.2 Where direct calculation procedures are employed supporting documentation is to be submitted for appraisal and this is to include details of the following:

- Calculation methods, assumptions and references.
- Loading.
- Structural modelling.
- Design criteria and their derivation, e.g., permissible stresses, factors of safety against plate panel instability, etc.

2.2.3 LR will be ready to consider the use of Builders' programs for direct calculations in the following cases:

(a) Where it can be established that the program has previously been satisfactorily used to perform a direct calculation similar to that now submitted.

(b) Where sufficient information and evidence of satisfactory performance is submitted to substantiate the validity of the computation performed by the program.

Section 3
National and International Regulations

3.1 International Conventions

3.1.1 The Committee, when authorised, will act on behalf of National Administrations and, if requested, LR will certify compliance in respect of National and International Statutory Safety and other requirements for offshore units.

3.1.2 In satisfying the Load Line Conventions, the general structural strength of the unit is required to be sufficient for the draught corresponding to the freeboards to be assigned. Units built and maintained in accordance with LR's Rules and Regulations possess adequate strength to satisfy the Load Line Conventions.

3.2 International Association of Classification Societies (IACS)

3.2.1 Where applicable, the Rules take into account unified requirements and interpretations established by IACS.

3.3 International Maritime Organization (IMO)

3.3.1 Attention is drawn to the fact that Codes of Practice issued by IMO contain requirements which are outside classification as defined in these Rules and Regulations.

Section 4
Information required

4.1 General

4.1.1 In general, the plans and information required to be submitted are given in 4.2.

4.1.2 Requirements for additional plans and information for functional unit types are given in Part 3.

4.1.3 Plans are generally to be submitted in triplicate, but only one copy of supporting documents and calculations will be required.

4.2 Plans and supporting information

4.2.1 Plans covering the following items are to be submitted for approval, as relevant to the type of unit:

- Bilge keel details.
- Bracings and associated primary structure.
- Corrosion control scheme.
- Deck structures including pillars and girders.
- Double bottom construction.
- Engine room construction.
- Equipment and supports.
- Erection sequence.
- Footings, pads or mats.
- Fore and aft end construction.
- Helideck.
- Ice strengthening.
- Leg structures and spuds.
- Loading manuals, preliminary and final.
- Machinery seatings.
- Main hull or pontoon structure.
- Masts and derrick posts.
- Materials and grades.
- Midship sections showing longitudinal and transverse material.
- Penetrations and attachments to primary structure.
- Profile and decks.
- Quality control and non-destructive testing procedures.
- Riser support structures.
- Rudder, stock, tiller and steering nozzles.
- Shell expansion.
- Stability columns.
- Stern frame and propeller brackets.
- Structural bulkheads and flats.
- Structure in way of jacking or elevating arrangements.
- Superstructures and deckhouses.
- Support structures for cranes, masts, derricks, flare towers and heavy equipment.
- Tank boundaries and overflows.
- Tank testing procedures and schedules.
- Temporary anchoring equipment.
- Towing arrangements and equipment.
- Transverse and longitudinal sections showing scantlings.
- Watertight sub-division.
- Watertight and oiltight bulkheads and flats.
- Watertight and weathertight doors and hatch covers.
- Welding details and procedures.

4.2.2 The following supporting plans and documents are to be submitted:

- General arrangements showing decks, profile and sections indicating all major items of equipment and machinery.
- Calculation of equipment number.
- Capacity plan.
- Cross curves of stability.
- Cross curves of allowable V.C.G.
- Design deck loading plan.
- Dry-docking plan.
- Operations Manual, *see* Pt 3, Ch 1,3.
- Tank sounding tables.
- Wind heeling moment curves.
- Lines plan or equivalent.

4.3 Calculations and data

4.3.1 The following calculations and information are to be submitted where relevant to the unit type and its design:

- Proposed class notations, operating areas and modes of operation, list of operating conditions stating proposed draughts.
- Design environmental criteria applicable to each mode, including wind speed, wave height and period, or sea state/wave energy spectra (as appropriate), water depth, tide and surge, current speed, minimum air temperature, ice and snow loads, sea bed conditions.
- A summary of weights and centres of gravity of lightship items.
- A summary of all items of deadweight, deck stores/supplies, fuel, fresh water, drill water, bulk and sack storage, crew and effects, deck loads (actual, not design allowables), riser, guideline, mooring tensions, hook or derrick loads and ballast schedules. The summary should be given for each operating condition.
- Details of distributed and concentrated gravity and live design loadings including crane overturning moments.
- Tank content data, and design pressure heads.
- Details of tank tests, model tests, etc.
- Strength and fatigue calculations.
- Calculation of hull girder still water bending moment and shear force as applicable.
- Calculation of hull girder section modulus at midships and elsewhere as required by LR.
- Stability calculations for intact and damaged cases covering a range of draughts to include all loading conditions.
- Documentation of damage cases, watertight sub-division and limits for downflooding.
- Freeboard calculation.

4.4 Specifications

4.4.1 Adequate design specifications in appropriate detail are to be submitted for information.

4.4.2 Specifications for the design and construction of the hull and structure are to include materials, grades/standards, welding construction procedures and fabrication tolerances.

4.4.3 Specifications related to the unit's proposed operations are to include environmental criteria, modes of operation and a schedule of all model tests with reports on minimum air gap, motion predictions, mooring analysis, etc.

4.5 Plans to be supplied to the unit

4.5.1 The following plans and documents are to be placed on board the unit, *see* Pt 3, Ch 1,2:

- Operations Manual.
- Loading Manual.
- Construction Booklet.
- Main scantlings plans.
- Corrosion control system.

4.5.2 Where an **OIWS** (In-water Survey) notation is to be assigned, approved plans and information covering the items detailed in Pt 3, Ch 1,2 are also to be placed on board.

4.5.3 Where a ShipRight **CM** (Construction Monitoring) notation or descriptive note is to be assigned, the approved Construction Monitoring Plan (CMP), as detailed in the *ShipRight Construction Monitoring Procedures*, is to be maintained on board the unit.

■ *Section 5* **Definitions**

5.1 General

5.1.1 **Rule length, *L*,** in metres, for self-elevating units and semi-submersible units with twin lower hulls is to be taken as 97 per cent of the extreme length on the maximum design transit waterline measured on the centreline or on a projection of the centreline, *see* Fig. 1.5.1.

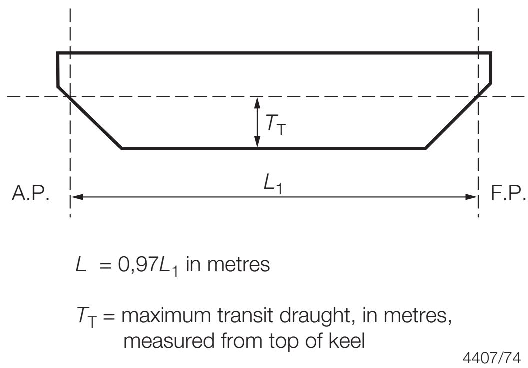


Fig. 1.5.1
Rule length for self-elevating units and semi-submersible units with twin lower hulls

5.1.2 The **Rule length, *L*,** for surface type units is the distance, in metres, on the summer load waterline from the forward side of the stem to the after side of the rudder post or to the centre of the rudder stock if there is no rudder post. L is to be not less than 96 per cent, and need not be greater than 97 per cent, of the extreme length on the summer load waterline. In ships with unusual stem or stern arrangements the Rule length, L, will be specially considered.

5.1.3 The Rule length for units with unconventional form will be specially considered in relation to the transit or operating waterlines.

5.1.4 **Breadth, *B***, is the greatest moulded breadth, in metres.

5.1.5 **Depth, *D***, is measured, in metres, at the middle of the length, *L*, from the top of keel to top of the deck beam at side on the uppermost continuous deck.

5.1.6 **Draught, T_0**, is the maximum design operating summer draught, in metres, measured from top of keel.

5.1.7 **Draught, T_T**, is the maximum design transit summer draught, in metres, measured from top of keel.

5.1.8 The **block coefficient, C_b**, is the moulded block coefficient corresponding to the maximum design draught *T* based on the Rule length *L* and moulded breadth *B* as follows:

$$C_b = \frac{\text{Moulded displacement (m}^3\text{) at draught } T}{LBT}$$

where

$T = T_0$ for surface type units

$T = T_T$ for self-elevating and semi-submersible units.

5.1.9 In general, the forward perpendicular, F.P., is the perpendicular at the intersection of the waterline at the draught *T* with the fore end of the hull. The aft perpendicular, A.P., is the perpendicular at the intersection of the waterline at the draught *T* with the aft end of the hull, *see also* 5.1.2.

5.1.10 Amidships is to be taken as the middle of the Rule length, *L*, measured from the forward side of the stem or hull.

5.1.11 **Lightweight** is defined as the weight of the complete unit with all its permanently installed machinery, equipment and outfit, including permanent ballast, spare parts normally retained on board, and liquids in machinery and piping to their normal working levels, but does not include liquids in storage or reserve supply tanks, items of consumable or variable loads, stores or crew and their effects.

■ *Section 6*
Inspection, workmanship and testing

6.1 General

6.1.1 Requirements regarding inspection, workmanship and testing are given in Pt 3, Ch 1,8 of the Rules for Ships and Ch 13,2 of the Rules for Materials and should be complied with.

Section 1 Materials of construction

1.1 General

1.1.1 The Rules relate in general to the construction of steel units, although consideration will be given to the use of other materials. For the use of aluminium alloys, *see* 1.3.

1.1.2 The materials used in the construction of the unit are to be manufactured and tested in accordance with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials). Materials for which provision is not made therein may be accepted, provided that they comply with an approved specification and such tests as may be considered necessary, *see also* Pt 3, Ch 1,4.

1.1.3 As an alternative, materials which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of the Rules for Materials or are approved for a specific application, e.g., legs of self-elevating units. Generally, survey and certification are to be carried out in accordance with the requirements of the Rules for Materials.

1.2 Steel

1.2.1 Steel having a specified minimum yield stress of 235 N/mm^2 (24 kgf/mm^2) is regarded as mild steel. Steel having a higher specified minimum yield stress is regarded as higher tensile steel.

1.2.2 When higher tensile steel is used in the construction of the unit the local scantlings determined from the Rules for steel plating, longitudinals, stiffeners and girders, etc., may be based on a *k* factor determined as follows:

$$k = \frac{235}{\sigma_o} \left(k = \frac{24}{\sigma_o} \right)$$

or 0,66, whichever is the greater

where

σ_o = specified minimum yield stress, of the higher tensile steel in N/mm^2 (kgf/mm^2).

1.2.3 When higher tensile steel is used in the primary structure of ship units, the determination of the hull girder section modulus is to be based on a higher tensile steel factor k_L determined in accordance with Table 2.1.1.

1.2.4 For the application of the requirements of 1.2.2 and 1.2.3, special consideration will be given to steel where σ_o > 355 N/mm^2 (36 kgf/mm^2). Where such steel grades are used in areas which are subject to fatigue loading, the structural details are to be verified using fatigue design assessment methods.

1.2.5 Where steel castings or forgings are used for major structural components, they are to comply with Chapter 4 or Chapter 5 of the Rules for Materials, as appropriate.

1.3 Aluminium

1.3.1 The use of aluminium alloy is permitted for superstructures, deckhouses, hatch covers, helicopter platforms, or other local components on board offshore units, except where stated otherwise in Pt 3, Ch 1,4.5.

1.3.2 Except where otherwise stated, equivalent scantlings are to be derived as follows:

Plating thickness:

$$t_a = t_s \sqrt{k_a}\, c$$

Section modulus of stiffeners:

$$Z_a = Z_s k_a c$$

where

c = 0,95 for high corrosion resistant alloy
= 1,0 for other alloys

$k_a = \dfrac{235}{\sigma_o}$

t_a = thickness of aluminium plating
t_s = thickness of mild steel plating
Z_a = section modulus of aluminium stiffener
Z_s = section modulus of mild steel stiffener
σ_a = 0,2 per cent proof stress or 70 per cent of the ultimate strength of the material, whichever is the lesser.

1.3.3 In general, for welded structure, the maximum value of σ_a to be used in the scantlings derivation is that of the aluminium in the welded condition. However, consideration will be given to using unwelded values depending upon the weld line location, or other heat affected zones, in relation to the maximum applied stress on the member (e.g., extruded sections).

1.3.4 A comparison of the mechanical properties for selected welded and unwelded alloys is given in Table 2.1.2.

1.3.5 Where strain hardened grades (designated Hxxx) are used, adequate protection by coating is to be provided to avoid the risk of stress corrosion cracking.

1.3.6 The use of aluminium alloy for primary structure will be specially considered.

Table 2.1.1 Values of k_L

Specified minimum yield stress In N/mm^2 (kgf/mm^2)	k_L
235 (24)	1,0
265 (27)	0,92
315 (32)	0,78
355 (36)	0,72
390 (40)	0,66
460 (47)	0,62

NOTES
1. Intermediate values by linear interpolation.
2. For the purpose of calculating hull moment of inertia as specified in Pt 3, Ch 4,5.8.1 of the Rules for Ships, k_L=1,0.

Table 2.1.2 Minimum mechanical properties for aluminium alloys

Alloy	Condition		0,2% proof stress, N/mm^2		Ultimate tensile strength, N/mm^2	
			Unwelded	Welded (*see* Note 4)	Unwelded	Welded (*see* Note 4)
5083	O/H111		125	125	275	275
5083	H112		125	125	275	275
5083	H116/H321		215	125	305	275
5383	O/H111		145	145	290	290
5383	H116/H321		220	145	305	290
5086	O/H111		100	95	240	240
5086	H112		125 (*see* Note 2)	95	250 (*see* Note 2)	240
5086	H116/H321		195	95	275	240
5059	O/H111		160	160	330	330
5059	H116/H321		260	160	360	300
5456	O		125	125	285	285
5456	H116		200 (*see* Note 5)	125	290 (*see* Note 5)	285
5456	H321		215 (*see* Note 5)	125	305 (*see* Note 5)	285
5754	O/H111		80	80	190	190
6005A (*see* Note 1)	T5/T6	Extruded: Open Profile Extruded: Closed Profile	215 215	100 100	260 250	160 160
6061 (*see* Note 1)	T5/T6	Rolled Extruded: Open Profile Extruded: Closed Profile	240 240 205	125 125 125	290 260 245	160 160 160
6082	T5/T6	Rolled Extruded: Open Profile Extruded: Closed Profile	240 260 240	125 125 125	280 310 290	190 190 190

NOTES
1. These alloys are not normally acceptable for application in direct contact with sea-water.
2. *See also* Table 8.1.4 in Chapter 8 of the Rules for Materials.
3. The mechanical properties to be used to determine scantlings in other types and grades of aluminium alloy manufactured to National or proprietary standards and specifications are to be individually agreed with LR, *see also* Ch 8,1.1.5 of the Rules for Materials.
4. Where detail structural analysis is carried out, 'Unwelded' stress values may be used away from heat affected zones and weld lines, *see also* 1.3.3.
5. For thickness less than 12,5 mm the minimum unwelded 0,2% proof stress is to be taken as 230 N/mm^2 and the minimum tensile strength is to be taken as 315 N/mm^2.

Section 2
Structural categories

2.1 General

2.1.1 For the determination of steel grades in accordance with 4.1, all structural components of the unit may be grouped into structural categories taking into account the following aspects:

(a) Applied loading, stress level and the associated stress pattern.
(b) Critical load transfer points and stress concentrations.
(c) Consequence of failure.

2.1.2 The structural categories can be summarised as follows:

(a) **Special structure**:
Primary structural elements which are in way of critical load transfer points and stress concentrations.
(b) **Primary structure**:
Structural elements essential to the overall integrity of the unit.
(c) **Secondary structure**:
Structural elements of less importance than primary structure, failure of which would be unlikely to affect the overall integrity of the unit.

2.1.3 For the structural categories of supporting structures of drilling plant and production and process plant, *see* Pt 3, Ch 7,2.2 and Ch 8,2.2 respectively.

2.2 Column-stabilised units

2.2.1 In general, the structural members of column-stabilised units are to be grouped into the following structural categories:

(a) **Special structure**:
 (i) The plating of decks, heavy flanges, shell boundaries and bulkheads of the upper hull or platform which form 'box' or 'I' type supporting structure in way of critical load transfer points and which receive major concentrated loads.
 (ii) The shell plating in way of the intersections of vertical columns with platform decks and upper and lower hulls.
 (iii) End connections and major intersections of primary bracing members.
 (iv) Critical load transfer by 'through' material used at connections of vertical columns, upper platform decks and upper or lower hulls which are designed to provide proper alignment and adequate load transfer.
 (v) External brackets, portions of bulkheads, flats, and frames which are designed to receive concentrated loads at intersections of major structural members.
(b) **Primary structure**:
 (i) The plating of decks, heavy flanges, shell boundaries and bulkheads of the upper hull or platform which form 'box' or 'I' type supporting structure except where the structure is considered as special application.
 (ii) The shell plating of vertical columns, lower and upper hulls, and diagonal and horizontal braces.
 (iii) Bulkheads, flats or decks, stiffeners and girders which provide local reinforcement or continuity of structure in way of intersections, except areas where the structure is considered as special application.
 (iv) Main support structure to cantilevered helicopter decks and lifeboat platforms.
 (v) Heavy substructures and equipment supports, e.g., drillfloor substructure, crane pedestals, anchor line fairleads and their supporting structure, *see also* 2.1.3.
 (vi) Riser support structure.
(c) **Secondary structure**:
 (i) Upper platform decks or decks of upper hulls, except areas where the structure is considered as primary or special application.
 (ii) Bulkheads, stiffeners, flats, decks, girders and web frames in vertical columns, upper and lower hulls, diagonal and horizontal bracing, which are not considered as primary or special application.
 (iii) Helicopter platforms and deckhouses.
 (iv) Lifeboat platforms.

2.3 Self-elevating units

2.3.1 In general, the structural members of self-elevating units are to be grouped into the following categories:

(a) **Special structure**:
 (i) Vertical columns in way of intersections with the mat structure.
 (ii) Intersections of lattice type leg structures which incorporate novel construction, including the use of steel castings.
(b) **Primary structure**:
 (i) The plating of bulkheads, decks and shell boundaries of the main hull or platform which in combination form 'box' or 'I' type main supporting structure.
 (ii) External plating of cylindrical legs.
 (iii) Plating of all components of lattice type legs.
 (iv) Jack-house supporting structure.
 (v) External shell plating of footings and mats and structural components which receive initial transfer of loads from the leg structures.
 (vi) Internal bulkheads and girders of supporting structure of footings and mats which are designed to distribute major concentrated or uniform loads into the structure.
 (vii) Main support structure to cantilevered helicopter decks and lifeboat platforms.
 (viii) Heavy substructures and equipment supports, e.g., drillfloor substructure, drilling cantilevers and crane pedestals, *see also* 2.1.3.
(c) **Secondary structure**:
 (i) Deck and shell boundaries of the main hull or platform, except where the structure is considered as primary application.
 (ii) Internal bulkheads, decks stiffeners and girders of the main hull structure, except where the structure is considered as primary structure.
 (iii) Internal diaphragms, girders or stiffeners in cylindrical legs.

(iv) Internal bulkheads, stiffeners and girders of footings and bottom mat supporting structures, except where the structure is considered primary or special application.
(v) Helicopter platforms and deckhouses.
(vi) Lifeboat platforms and walkways.

2.4 Surface type units

2.4.1 Material classes and steel grades for individual areas of the hull structure of ship and barge type units are to comply with Pt 3, Ch 2,2 of the Rules for Ships.

2.4.2 Where the minimum design temperature, *see* 3.1, for exposed structure is –5°C or below, or for structural components not addressed by 2.4.1, the requirement of 2.4.3 should be complied with and the steel grades should be assigned in accordance with Table 2.4.1.

2.4.3 In general, the structure of ship type units is to be grouped into the following structural categories:

(a) **Special structure**:
(i) Structure in way of critical load transfer points which are designed to receive major concentrated loads in way of mooring systems, including yokes and similar structures, and supports to hawsers to mooring installations including external hinges, complex padeyes, brackets and supporting structures.
(ii) Sheerstrake or rounded gunwale.
(iii) Stringer plate at strength deck.
(iv) Deck strake at longitudinal bulkheads.
(v) Bilge strake.
(vi) Continuous longitudinal hatch coamings.

(b) **Primary structure**:
(i) Strength deck and raised quarter deck plating except where categorised '**special**'.
(ii) Bottom shell plating of the main hull except where categorised '**special**'.
(iii) Bulkhead plating in way of moonpools, drilling wells and circumturret.
(iv) Upper strake in longitudinal bulkheads.
(v) Continuous longitudinal members above strength deck except where categorised '**special**'.
(vi) Vertical strake (hatch side girder) and upper sloped strake in top wing tanks.
(vii) Main support structure to cantilevered helicopter decks and lifeboat platforms.
(viii) Heavy substructures and equipment supports, e.g. integrated support stools to process plant, drill floor substructure, crane pedestals, anchor line fairleads and chain stoppers for positional mooring systems and their supporting structures, *see also* 2.1.3.
(ix) Riser support structures.

(c) **Secondary structure**:
(i) Bulkhead plating, side shell, longitudinals, stiffeners, deck plating including poop deck and forecastle deck, flats, girders and web frames, etc., except where the structure is categorised as **special** or **primary** structure. For topside plant supporting structures, *see also* 2.1.3.
(ii) Helicopter platforms and deckhouses.
(iii) Lifeboat platforms, walkways, guard rails, minor fittings and attachments, etc.

Section 3
Design temperature

3.1 General

3.1.1 The Minimum Design Temperature (MDT) is a reference temperature used as a criterion for the selection of the grade of steel to be used in the structure and is to be determined in accordance with Pt 3, Ch 1,4.

3.1.2 The MDT is not to exceed the lowest service temperature of the steel as appropriate to the position in the structure.

3.1.3 A design temperature of 0°C is generally acceptable for determining the steel grades for structure which is normally underwater, *see also* 4.1.4.

3.1.4 For column-stabilised units of conventional design, the lower hulls need not normally be designed for a design temperature lower than 0°C.

3.1.5 The design temperature for internal structure of all units is to be separately defined, *see* Lloyd's Register's *Provisional Rules for the Winterisation of Ships*.

3.1.6 Internal structures in way of permanently heated compartments need not normally be designed for temperatures lower than 0°C.

Section 4
Steel grades

4.1 General

4.1.1 The grades of steel to be used in the structure are, in general, related to the thickness of the material, the structural category and the MDT. The grades of steel to be used in the construction of the unit are to be determined from Table 2.4.1, *see also* 4.1.5 and Section 2. Material thicknesses greater than those shown in Table 2.4.1 may be specially considered by LR, e.g., legs of self-elevating units.

4.1.2 Special consideration will be given to the use of higher tensile steel grades with a minimum yield stress greater than 390 N/mm^2, e.g., legs of self-elevating units.

4.1.3 Material where the principal loads or welding stresses are perpendicular to the plate thickness should have suitable through-thickness properties. The application of through-thickness property Z25 or Z35 grade material is required where tensile stresses exceed 50 per cent of the Rule permissible stress, with plate thickness in excess of 15 mm. In general, Z25 grade would be required; however, for critical joints, Z35 will be required. For certain critical joints with a restricted load path this criterion would be subject to special consideration, for example, mooring fairlead attachments and anchor line or hawser connections.

Table 2.4.1 Thickness limitations for hull structural steels for various application categories and design temperatures for use in welded construction

Structural category	Required steel grade	Maximum thickness permitted (mm) for various minimum design temperatures, *see* Note 8			
		0°C	–10°C	–20°C	–30°C
Secondary	A	30	20	12,5	X
	B	60	50	25	10
	D	100	100	80	50
	E	150	150	120	100
	AH	50	40	25	10
	DH	100	100	70	50
	EH	150	150	100	80
	FH	150	150	150	120
	AQ	50	40	25	10
	DQ	100	100	70	50
	EQ	150	150	120	80
	FQ	150	150	150	120
Primary	A	20	12,5	X	X
	B	25	25	12,5	X
	D	50	50	30	20
	E	100	100	65	40
	AH	25	25	12,5	X
	DH	50	50	30	20
	EH	120	100	65	40
	FH	150	150	150	100
	AQ	25	25	X	X
	DQ	50	50	30	20
	EQ	120	100	65	40
	FQ	150	150	150	100
Special	A	12.5	X	X	X
	B	15	12,5	X	X
	D	30	30	20	10
	E	100	75	35	30
	AH	20	12,5	X	X
	DH	30	30	12,5	10
	EH	100	75	35	25
	FH	150	100	80	50
	AQ	15	12,5	X	X
	DQ	30	30	12,5	10
	EQ	100	75	30	25
	FQ	150	100	80	60

NOTES
1. X indicates that the material is not permitted for that design temperature and structural category.
2. Materials are to comply with the requirements of Chapter 3 of the Rules for Materials.
3. Q grades refer to quenched and tempered grades (Ch 3,10 of the Rules for Materials).
4. The thicknesses refer to as constructed thicknesses (e.g., design thickness plus any allowances such as corrosion allowance).
5. Requirements for minimum design temperature lower than –30°C will require special consideration which may include the use of fracture mechanics assessments.
6. Thicknesses greater than those shown in this Table may be used subject to special consideration by LR and may include fracture mechanics assessment.
7. The interpolation of thicknesses for intermediate temperatures may be considered.
8. For LNG installations where the minimum hull shell plating temperature used in the design is the result of heat conduction from the cargo rather than environmental conditions, the material thicknesses shall be in accordance with Table 6.5 in Pt 11, Ch 6 of the *Rules and Regulations for the Classification of a Floating Offshore Installation at a Fixed Location*.

4.1.4 Steel grades for units required to operate in severe ice conditions will be specially considered. Temperature gradient calculations may be required to assess the design temperature of the structure, *see also* Pt 3, Ch 6.

4.1.5 Minor structural components such as guard rails, walkways and ladders, etc., are, in general, to be constructed of Grade A steel, unless agreed otherwise by LR, *see also* 4.1.4.

4.1.6 For components listed in Table 2.4.2, special consideration may be given to material grades with other impact properties than those required by Table 2.4.1. In such cases, written agreement is required prior to manufacture. This evaluation is to be based on critical engineering assessment involving fracture mechanics testing on welded material from the intended supplier and proposals are to be submitted which include full details of the application, minimum temperature, design, design stresses, fatigue loads and cycles, welding procedures that will be applied and inspection procedures.

Table 2.4.2 Applications where fracture mechanics may be considered to permit alternative grades of steel

Application
Lattice type leg structures
Cylindrical legs
Footing and mats

Section 1 General

1.1 Application

1.1.1 This Chapter indicates the general design concepts and loading and the general principles adopted in applying the Rule structural requirements given in this Part.

1.1.2 General definitions of span point, derivation of geometric properties of section and associated effective area of attached plating are given in this Chapter.

1.1.3 Additional requirements relating to functional unit types are also dealt with under the relevant unit type given in Part 3.

1.1.4 General principles of subdivision and requirements for cofferdams are given in this Chapter.

1.1.5 For surface type units, Sections 2, 3 and 5 are not applicable.

1.1.6 Structural idealisation aspects of surface type units are to comply with Pt 3, Ch 3,3 of the Rules for Ships.

1.1.7 The number and arrangement of bulkheads on surface type units are given in Pt 3, Ch 3,4 of the Rules for Ships, which are to be complied with, as applicable.

1.1.8 For all unit types, structural design loads as given in Section 4 should be considered as applicable.

Section 2 Design concepts

2.1 Elastic method of design

2.1.1 In general, the approval of the primary structure of the unit will be based on the elastic method of design and the permissible stresses in the structure are to be based on the minimum factors of safety defined in Chapter 5. When specifically requested, LR will consider other design methods.

2.2 Limit state method of design

2.2.1 When the limit state method of design is proposed for the structure, the design methods, load combinations and partial factors are to be agreed with LR.

2.3 Plastic method of design

2.3.1 When the plastic method of design based on the ultimate strength is proposed for the structure, the load factors are to be in accordance with an acceptable Code of Practice, *see* Pt 3, Appendix A.

2.4 Fatigue design

2.4.1 All units are to be capable of withstanding the fatigue loading to which they are subjected. The fatigue design requirements are given in Ch 5,5.

Section 3 Structural idealisation

3.1 General

3.1.1 In general, the primary structure of a unit is to be analysed by a three-dimensional finite plate element method. Only if it can be demonstrated that other methods are adequate will they be considered.

3.1.2 The complexity of the mathematical model together with the associated computer element types used must be sufficiently representative of all the parts of the primary structure to enable accurate internal stress distributions to be obtained.

3.1.3 When requested, LR can perform an independent structural analysis of the unit.

3.1.4 For derivation of local scantlings of stiffeners, beams, girders, etc., the formulae in the Rules are normally based on elastic or plastic theory using simple beam models supported at one or more points and with varying degrees of fixity at the ends, associated with an appropriate concentrated or distributed load.

3.1.5 Apart from local requirement for web thickness or flange thicknesses, the stiffener, beam or girder strength is defined by a section modulus and moment of inertia requirement.

3.2 Geometric properties of section

3.2.1 The symbols used in this sub-Section are defined as follows:

b = actual width, in metres, of the load-bearing plating, i.e. one-half of the sum of spacings between parallel adjacent members or equivalent supports

f = $0{,}3\left(\dfrac{l}{b}\right)^{2/3}$ but is not to exceed 1,0. Values of this factor are given in Table 3.3.1

l = overall length, in metres, of the primary support member, *see* Fig. 3.3.3

t_p = thickness, in mm, of the attached plating. Where this varies, the mean thickness over the appropriate span is to be used.

Table 3.3.1 Effective width factor

$\dfrac{l}{b}$	f	$\dfrac{l}{b}$	f
0,5	0,19	3,5	0,69
1,0	0,30	4,0	0,76
1,5	0,39	4,5	0,82
2,0	0,48	5,0	0,88
2,5	0,55	5,5	0,94
3,0	0,62	6 and above	1,00

NOTE
Intermediate values to be obtained by linear interpolation.

3.2.2 The effective geometric properties of rolled or built sections may be calculated directly from the dimensions of the section and associated effective area of attached plating. Where the web of the section is not normal to the attached plating, and the angle exceeds 20°, the properties of the section are to be determined about an axis parallel to the attached plating.

3.2.3 The geometric properties of rolled or built stiffener sections and of swedges are to be calculated in association with effective area of attached load bearing plating of thickness t_p mm and of width 600 mm or $40t_p$ mm, whichever is the greater. In no case, however, is the width of plating to be taken as greater than either the spacing of the stiffeners or the width of the flat plating between swedges, whichever is appropriate. The thickness, t_p, is the actual thickness of the attached plating. Where this varies, the mean thickness over the appropriate span is to be used.

3.2.4 The effective section modulus of a corrugation over a spacing p is to be calculated from the dimensions and, for symmetrical corrugations, may be taken as:

$$Z = \frac{d_w}{6000}\,(3bt_p + ct_w)\ \text{cm}^3$$

where

d_w, b, t_p, c and t_w are measured, in mm, and are as shown in Fig. 3.3.1. The value of b is to be taken not greater than:

$50t_p\sqrt{k}$ for welded corrugations

$60t_p\sqrt{k}$ for cold formed corrugations

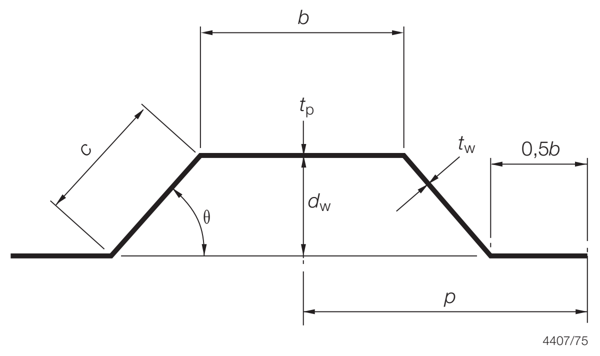


Fig. 3.3.1 Corrugation geometry

The value of θ is to be taken not less than 40°. The moment of inertia is to be calculated from:

$$I = \frac{Z}{10}\left(\frac{d_w}{2}\right)\ \text{cm}^4$$

3.2.5 The section modulus of a double plate bulkhead over a spacing b may be calculated as:

$$z = \frac{d_w}{6000}\,(6f\,b\,t_p + d_w\,t_w)\ \ \text{cm}^3$$

where

d_w, b, t_p and t_w are measured, in mm, and are as shown in Fig. 3.3.2.

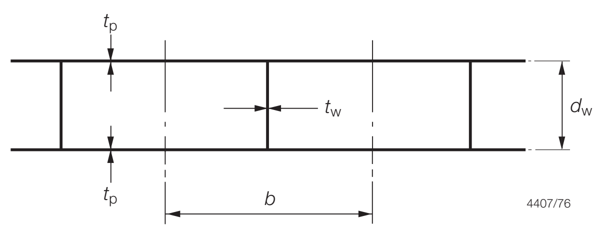


Fig. 3.3.2 Double plate bulkhead geometry

3.2.6 The effective section modulus of a built section may be taken as:

$$z = \frac{ad_w}{10} + \frac{t_w\,d_w^2}{6000}\left(1 + \frac{200(A-a)}{200A + t_w\,d_w}\right)\ \text{cm}^3$$

where

a = area of the face plate of the member, in cm^2

d_w = depth, in mm, of the web between the inside of the face plate and the attached plating. Where the member is at right angles to a line of corrugations, the minimum depth is to be taken

t_w = thickness of the web of the section, in mm

A = area, in cm^2, of the attached plating, *see* 3.2.7. If the calculated value of A is less than the face area a, then A is to be taken as equal to a.

3.2.7 The geometric properties of primary support members (i.e., girders, transverses, webs, stringers, etc.) are to be calculated in association with an effective area of attached load bearing plating, *A*, determined as follows:

(a) For a member attached to plane plating:

$A = 10 f\, b\, t_p \quad \text{cm}^2$

(b) For a member attached to corrugated plating and parallel to the corrugations:

$A = 10 b\, t_p \quad \text{cm}^2$

See Fig. 3.3.1.

(c) For a member attached to corrugated plating and at right angles to the corrugations, *A* is to be taken as equivalent to the area of the face plate of the member.

3.3 Determination of span point

3.3.1 The effective length, l_e, of a stiffening member is generally less than the overall length, l, by an amount which depends on the design of the end connections. The span points, between which the value of l_e is measured, are to be determined as follows:

(a) For rolled or built secondary stiffening members, the span point is to be taken at the point where the depth of the end bracket, measured from the face of the secondary stiffening member is equal to the depth of the member. Where there is no end bracket, the span point is to be measured between primary member webs. For double skin construction the span may be reduced by the depth of primary member web stiffener, *see* Fig. 3.3.3.

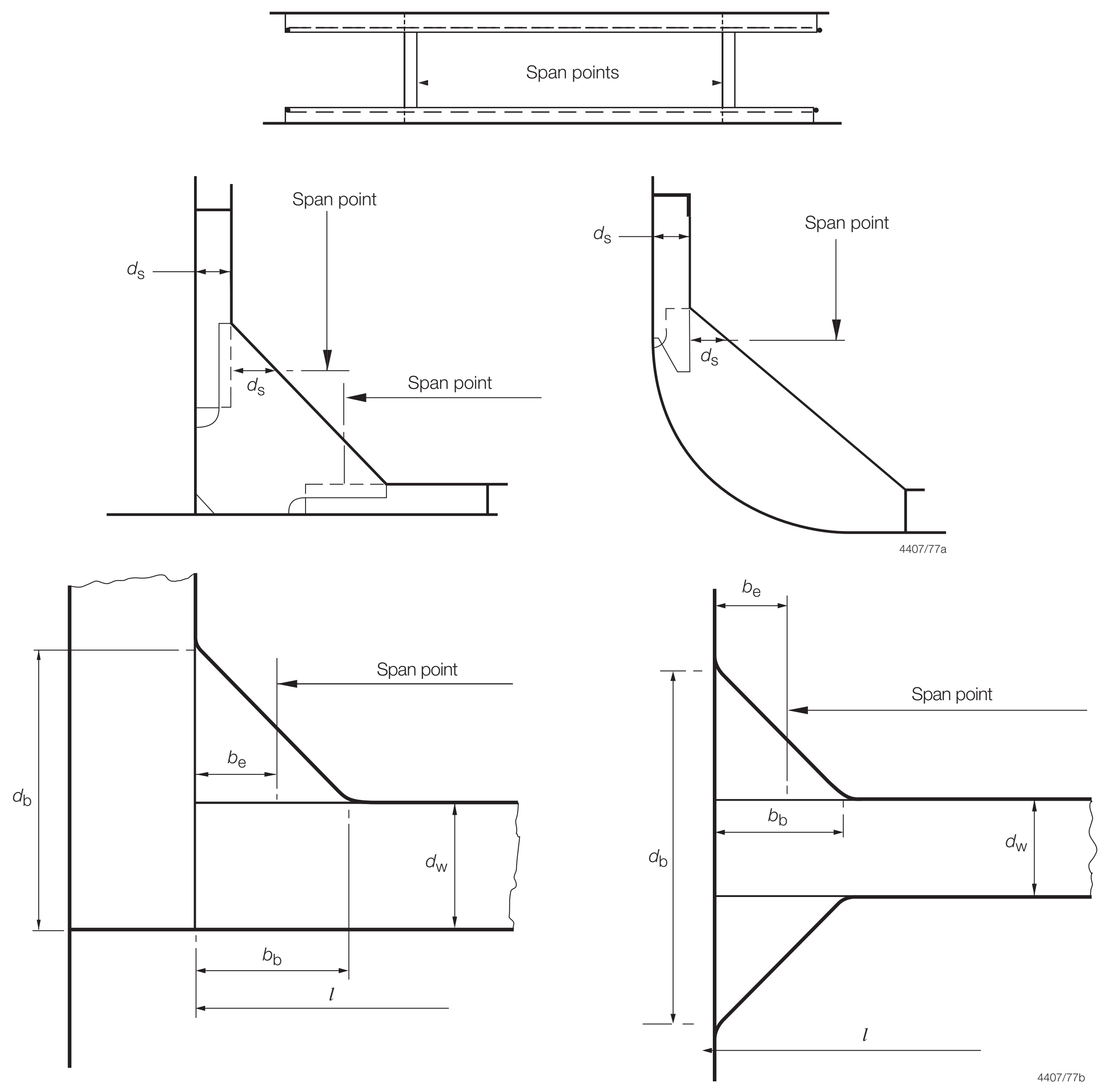


Fig. 3.3.3 Span points

(b) For primary support members: the span point is to be taken at a point distant b_e from the end of the member, where

$$b_e = b_b \left(1 - \frac{d_w}{d_b}\right)$$

See also Fig. 3.3.3.

3.3.2 Where the end connections of longitudinals are designed with brackets to achieve compliance with the *ShipRight FDA Procedure*, no reduction in span is permitted for such brackets unless the fatigue life is subsequently reassessed and shown to be adequate for the resulting reduced scantlings.

3.3.3 Where the stiffener member is inclined to a vertical or horizontal axis and the inclination exceeds 10°, the span is to be measured along the member.

3.3.4 It is assumed that the ends of stiffening members are substantially fixed against rotation and displacement. If the arrangement of supporting structure is such that this condition is not achieved, consideration will be given to the effective span to be used for the stiffener.

3.4 Grouped stiffeners

3.4.1 Where stiffeners are equally spaced and are arranged in groups of the same scantling, the section modulus requirement of each group is to be based on the greater of:

(a) the mean value of the section modulus required for individual stiffeners within the group; and

(b) 90 per cent of the maximum section modulus required for individual stiffeners within the group.

■ *Section 4* Structural design loads

4.1 General

4.1.1 The requirements in this Section define the loads and load combinations to be considered in the overall strength analysis of the unit and the design pressure heads to be used in the Rules for local scantlings.

4.1.2 A unit's modes of operation are to be investigated using realistic loading conditions, including buoyancy, gravity and functional loadings together with relevant environmental loadings. Due account is to be taken of the effects of wind, waves, currents, motions (inertia), moorings, ice, and, where necessary, the effects of earthquake, sea bed-supporting capabilities, temperature, fouling, etc. Where applicable, the design loadings indicated herein are to be adhered to for all types of offshore units.

4.1.3 The Owner/designer is to specify the modes of operation and the environmental conditions for which the unit is to be approved, *see also* Pt 1, Ch 2,2.

4.1.4 The design environmental criteria determining the loads on the unit and its individual elements are to be based upon appropriate statistical information and have a return period (period of recurrence) of at least 50 years for the most severe anticipated environment. If a unit is restricted to seasonal operations in order to avoid extremes of wind and wave, such seasonal limitations must also be specified.

4.1.5 Model tests are to be carried out as necessary and the tests are to include means of establishing the effects of green water loading and/or slamming on the structure through video recordings of the model testing and by measurement of the following:

- Relative motions.
- Forces on local panels mounted at various locations on exposed areas including bow areas of surface type units and accommodation areas, *see also* Chapter 4 and Pt 3, Ch 10,5.

4.1.6 When carrying out model tests, account is to be taken of the following:

- The test programme and the model test facilities are to be to LR's satisfaction.
- The relative directions of wind, wave and current are to be varied as required to ensure that the most critical loadings and motions are determined.
- The tests are to be of sufficient duration to establish low frequency motion behaviour.

4.1.7 The unit's limiting design criteria are to be included in the Operations Manual, *see* Pt 3, Ch 1,3.

4.2 Definitions

4.2.1 **Still water condition** is defined as an ideal condition when no environmental loads are imposed on the structure, e.g., no wind, wave or current, etc.

4.2.2 **Gravity and functional loads** are loads which exist due to the unit's weight, use and treatment in still water conditions for each design case. All external forces which are responses to functional loads are to be regarded as functional loads, e.g., support reactions and still water buoyancy forces.

4.2.3 **Environmental loads** are loads which are due directly or indirectly to environmental actions. All external forces which are responses to environmental loads are to be regarded as environmental loads, e.g., mooring forces and inertia forces.

4.2.4 **Accidental loads** are loads which occur as a direct result of an accident or exceptional circumstances, e.g., loads due to collisions, dropped objects and explosions, etc. *See also* 4.16.

4.3 Load combinations

4.3.1 The structure is to be designed for the most unfavourable of the following combined loading conditions (as relevant to the unit):

(a) Maximum gravity and functional loads.
(b) Design environmental loads and associated gravity and functional loads.
(c) Accidental loads and associated gravity and functional loads.
(d) Environmental loads and associated gravity and functional loads after credible failures or accidents.

NOTE
Load combination (c) relates to the loading and condition of the unit at the time of the accidental event. Load combination (d) relates to the loading and condition of the unit following the accidental event and allowing for agreed documented mitigation measures to be put in place. *See also* 4.16 and Chapter 4 for applicability to unit types.

4.3.2 Special requirements applicable to column-stabilised and self-elevating units are also defined in Chapter 4.

4.3.3 Permissible stresses relevant to the combined loading conditions are given in Chapter 5.

4.4 Gravity and functional loads

4.4.1 All gravity loads, including static loads such as weight, outfit, stores, machinery, ballast, etc., and live functional loads from operating derricks, cranes, winches and other equipment are to be considered. All practical combinations of gravity and functional loads are to be included in the design cases.

4.5 Buoyancy loads

4.5.1 Buoyancy loads on all underwater parts of the structure, taking account of heel and trim when appropriate, are to be considered.

4.6 Wind loads

4.6.1 Account is to be taken of the wind forces acting on that part of the unit which is above the still water level in all operating conditions and of the following:

(a) Consideration is to be given to wind gust velocities which are of brief duration and sustained wind velocities which act over intervals of time equal to or greater than one minute. Different wind velocity averaging time intervals applicable to different structural categories to be used in design calculations are shown in Table 3.4.1.
(b) Wind velocities are to be specified relative to a standard reference height of 10 m above still water level for each operating condition.

Table 3.4.1 Structural parts to be considered for wind loading

Windspeed averaging time interval	Structural category
3 second gust	Individual members and equipment secured to them
5 second mean (sustained)	Part or whole of a structure whose greatest horizontal or vertical dimension does not exceed 50 m
15 second mean (sustained)	Part or whole of a structure whose greatest horizontal or vertical dimension exceeds 50 m
1 minute mean (sustained) *see* Note	The whole structure of the unit regardless of dimension for use with the maximum wave and current loads
NOTE In no case is the one minute mean value to be taken less than 25,8 m/s.	

(c) The variation of wind velocity with height for each operating condition may be determined from the following expression:

$$V_H = V_R \left(\frac{H}{H_R}\right)^n$$

where

V_H = wind velocity at specified height, in m/s
V_R = wind velocity at specified reference height H_R, in m/s
H = specified height above sea level, in metres
H_R = reference height, in metres
n = power law exponent
for 3 second gust n = 0,077
for 5 second mean n = 0,08
for 15 second mean n = 0,09
for 1 minute mean n = 0,125
for 10 minute mean n = 0,13.

4.6.2 The wind force is to be calculated for each part of the structure and is not to be taken less than:

$$F = K_w A V^2 C_s \quad \text{N (kgf)}$$

where

F = net force acting on any member or part of the unit. This includes the effect of any suction on back surfaces
K_w = 0,613 (0,0625)
A = projected area of all exposed surfaces in upright or heeled position, in m^2
V = wind velocity, in m/s, *see* 4.6.1
C_s = shape coefficient as given in Table 3.4.2.

Table 3.4.2 Values of coefficient C_S

Shape	C_S
Spherical	0,40
Cylindrical	0,50
Large flat surface (hull, deckhouse, smooth underdeck areas)	1,00
Drilling derrick	1,25
Wires	1,20
Exposed beams and girders under deck	1,30
Small parts	1,40
Isolated shapes (cranes, booms, etc.)	1,50
Clustered deckhouses or similar structures	1,10
NOTE Shapes or combinations of shapes which do not readily fall into the specified categories will be subject to special consideration.	

4.6.3 When calculating wind forces the following procedures should be considered:

(a) Shielding may be taken into account when a member or structure lies closely enough behind another to have a significant effect. Procedures for determining the shielding effect and loading are to be acceptable to LR.
(b) Areas exposed due to heel, such as underdecks, etc., are to be included using the appropriate shape coefficients.
(c) If several deckhouses or structural members, etc., are located close together in a plane normal to the wind direction, the solidification effect is to be taken into account. The shape coefficient may be assumed to be 1,1.
(d) Isolated houses, structural shapes, cranes, etc., are to be calculated individually, using the appropriate shape coefficient.
(e) Open truss work commonly used for derrick towers, booms and certain types of masts may be approximated by taking 30 per cent of the projected block area of each side, e.g., 60 per cent of the projected block area of one side for double-sided truss work. An appropriate shape coefficient is to be taken from Table 3.4.2.

4.6.4 For slender structures and components, the effects of wind-induced cross-flow vortex vibrations are to be included in the design loading.

4.6.5 For slender structures sensitive to dynamic loads, the static gust wind force is to be multiplied by an appropriate dynamic amplification factor.

4.7 Current loads

4.7.1 In storm conditions, the current has two main components: the tidal and wind driven components. Submitted information on currents is to include tidal and wind induced components and the variation of their profiles with water depth, *see* 4.9.6 and 4.9.7. In addition, the effects of general circulation and loop currents are to be included where appropriate.

4.8 Orientation and wave direction

4.8.1 Loadings are to be assessed using sufficient wave headings and crest positions to determine the most severe loading on the unit. In addition to the maximum limiting wave height and associated periods, the unit is to be designed to withstand shorter period waves of less height when these can induce more severe loading on parts or the whole unit due to dynamic effects, etc.

4.8.2 Where a unit is required to operate at locations exposed to wind waves and swell waves acting simultaneously then this is to be taken into account when determining the wave loads.

4.9 Wave loads

4.9.1 Design wave criteria specified by the Owner/designer may be described either by means of design wave energy spectra or deterministic design waves having appropriate shape, size and period. The following should be taken into account:

(a) The maximum design wave heights specified for each operating condition should be used to determine the maximum loads on the structure and principal elements. Consideration is to be given to waves of less than maximum height, where due to their period, the effects on various structural elements may be greater.
(b) Wave lengths are to be selected as the most critical ones for the response of the structure or element to be investigated.
(c) An estimate is to be made of the probable wave encounters that the unit is likely to experience during its service life in order to assess fatigue effects on its structural elements.
(d) When units are to operate in intermediate or shallow water, the effect of the water depth on wave heights and periods and of refraction due to sea bed topography is to be taken into account.

4.9.2 The forces produced by the action of waves on the unit are to be taken into account in the structural design, with regard to forces produced directly on the immersed elements of the unit and forces resulting from heeled positions or accelerations due to its motion. Theories used for the calculation of wave forces and selection of relevant coefficients are to be acceptable to LR.

4.9.3 The wave forces may be assessed from tests on a representative model of the unit by a recognised laboratory, *see* 4.1.5 and 4.1.6.

4.9.4 Wave theories used for the calculation of water particle motions are to be acceptable to LR and when using acceptable wave theories for wave force determination, reliable values of C_D and C_M which have been obtained experimentally for use in conjunction with the specific wave theory are to be used. Otherwise published data are to be used.

4.9.5 Consideration is to be given to the possibility of wave impact and wave induced vibration in the structure.

4.9.6 Where sea current acts simultaneously with waves, the effect of the current is to be included in the load estimation.

4.9.7 The following methods may be used for load estimation:

(a) The forces on structural elements with dimensions less than 0,2 of the wave length subject to drag/inertia loading due to wave and current motions can be calculated from the Morison's equation:

$F = 0{,}5C_D\,\rho\,Au\,|u| + C_M\,\rho\,V\,a$

where

F = force per unit length of member
C_D = drag coefficient
ρ = density of water
A = projected area of member per unit length
u = component of the water particle velocity at the axis of the member and normal to it (calculated as if the member were not there)
$|u|$ = modulus of u
C_M = inertia coefficient
V = volume of water per unit length
a = component of the water particle acceleration at the axis of the member and normal to it (calculated as if the member were not there)

(b) Overall loading on an offshore structure is determined from the summation of loads on individual members at a particular time. The proper values of C_D and C_M for individual members to use with Morison's equation will depend on a number of variables, for example: Reynolds number, Keulegan-Carpenter number, inclination of the member to local flow and effective roughness of marine growth. Therefore, fixed values for all conditions cannot be given. Typical values for circular cylindrical members, will range from 0,6 to 1,4 for C_D and 1,3 to 2,0 for C_M. The values selected are not to be smaller than the lower limits of these ranges. For inclined members, the drag forces in Morison's equation are to be calculated using the normal component of the resultant velocity vector.

(c) General values of hydrodynamic coefficients may be used in the Morison's equation for the calculation of overall loading on the structure, namely:
- For circular cylinders covered by hard marine growth, C_D is to be not less than 0,7.
- For circular cylinders not covered by hard marine growth, C_D is to be not less than 0,6.
- For circular cylinders, C_M is to be not less than 1,7.

If joint probability predictions of wave and current are included in the design procedure or if the conservatism is reduced in any part, consideration is to be given to increasing the drag coefficient associated with marine growth.

(d) Diffraction theory is normally appropriate to determine wave loads where the member is large enough to modify the flow field.

4.9.8 Account is to be taken of the increase of overall size and roughness of submerged members due to marine growth when calculating loads due to wave and current, *see* 4.13.

4.10 Inertia loads

4.10.1 Dynamic loads imposed on the structure by accelerations due to the unit's motion in a seaway are to be included in the structural design calculations. The dynamic loads may be obtained from model test results or by calculation. The methods of calculation are to be acceptable to LR.

4.11 Mooring loads

4.11.1 Mooring loads are to be considered for units operating afloat with positional mooring systems, *see* Pt 3, Ch 10. The following are to be considered:
- The overall strength of the structure.
- The local strength where the mooring line forces are transmitted to the hull.

4.11.2 The support structure in way of mooring equipment is to be designed for the minimum design breaking load of the mooring line, determined in accordance with Pt 3, Ch 10. *See also* Ch 6,1.

4.12 Snow and ice loads

4.12.1 Consideration is to be given to the extent to which snow and ice may accumulate on the exposed structure under any particular weather conditions. The wind resistance of exposed structural elements will be increased by the growth of ice. Details of the thickness and distribution of accumulation are to be established and taken into account in the design, *see also* Pt 3, Ch 6.

4.12.2 The increased loading caused by the accumulation of snow and ice on any part of the structure is to be taken into account.

4.12.3 Values for the thickness, density and variation with height of accumulated snow and ice are to be derived from meteorological data acceptable to LR.

4.12.4 The overall distribution of snow and/or ice on topside structure is to be taken as a thickness t_i on the upper and windward faces of the deck structures or members under consideration, where t_i is the basic thickness obtained from the meteorological data. The distribution of ice on individual members may be assumed to be as shown in Fig. 3.4.1.

4.12.5 It may be assumed that there is no increase of drag coefficient in the presence of ice.

4.12.6 The appropriate combinations of snow and ice loadings with other design environmental loads are to be specially considered and agreed with LR. In general, extreme snow and ice loads are to be combined with other environmental loads corresponding to the design five-year return criteria for the unit.

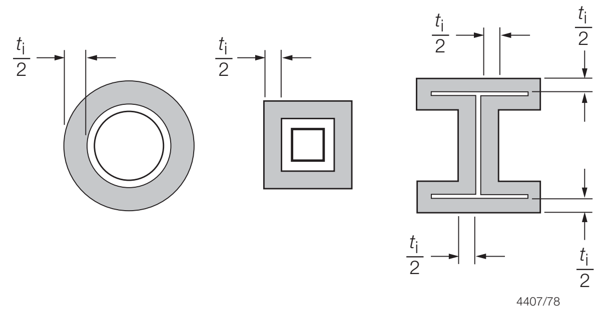


Fig. 3.4.1
Assumed distribution of ice on individual members for calculation purposes

4.13 Marine growth

4.13.1 Marine growth will increase the weight and the overall dimensions of submerged members and alter their surface characteristics. These effects will increase the loads applied to the structure. The thickness of marine growth taken into account in the design is to be stated in the Operations Manual and the design limit is not to be exceeded in service.

4.14 Hydrostatic pressures

4.14.1 The pressure head to be used as the basis for the design of internal spaces is to be the greatest of the following:

(a) For tanks, the maximum head during normal operation.
(b) For shell boundaries, the hydrostatic head due to external pressure arising from the sea, taking maximum wave crest elevation in both operating and survival conditions with a minimum head of 6 m on semi-submersible units.
(c) For watertight boundaries, the head measured to the worst damage waterline, *see* Chapter 7.
(d) The minimum design pressure heads for local strength are to be in accordance with Chapter 6.

4.14.2 Where testing the tank involves pressure heads in excess of those derived in 4.14.1, the excess may be taken into account by the use of a load factor applied to the design head. Where this is done, it is to be clearly stated in the calculations.

4.15 Deck loads

4.15.1 The maximum design uniform and concentrated deck loads for all areas of the unit in each mode of operation are to be taken into account in the design. The minimum design deck loads for local strength are to be in accordance with Chapter 6.

4.16 Accidental loads

4.16.1 The following credible failures and accidents are to be considered in the design as applicable to the function of the unit.

- Collision.
- Dropped object.
- Blast.
- Accidental flooding.
- Loss of primary bracing (column-stabilised unit).

4.16.2 Collision loads imposed by attending vessels which may be approaching, mooring or lying alongside the unit are to be considered in the design. The unit is to be designed to withstand accidental impacts between attending vessels and the unit and be capable of absorbing the impact energy.

4.16.3 The kinetic energy to be considered is normally not to be less than:

- 14 MJ for sideway collision;
- 11 MJ for bow or stern collision;

corresponding to an attending vessel of 5000 tonnes displacement with impact velocity 2 m/s.

4.16.4 A reduced impact energy may be accepted upon special consideration, taking into account the environmental design criteria.

4.16.5 The energy absorbed by the unit during a collision impact will be less than or equal to the total impact kinetic energy, depending on the relative stiffnesses of the relevant parts of the unit and the impacting ship/unit and also on the mode of collision and ship/unit operation. These factors may be taken into account when considering the energy absorbed by the unit, *see also* Ch 4,1 and Ch 4,3 for column-stabilised and self-elevating units respectively.

4.16.6 Collision is to be considered for all elements of the unit which may be hit by sideway, bow or stern collision. The vertical extent of the collision zone is to be based on the depth and draught of attending ships/units and the relative motion between the attending ships/units and the unit.

4.16.7 The accidental impact loads caused by dropped objects from cranes are to be considered in the design of the unit when the arrangements of the unit are such that the failure of a vital structure member could result in the collapse of the structure.

4.16.8 Critical areas for dropped objects are to be determined on the basis of the actual movement of crane loads over the unit.

4.16.9 The structural bulkheads protecting accommodation areas, and other structures that may be subject to blast pressures, are to be designed for accidental blast loading, where applicable. The design blast pressures are to be defined by the Owners/designers, *see* Pt 7, Ch 3,2.4.2 and are to comply with National requirements. Blast loads are to be combined with the still water loads. Environmental loads need not be considered. Design calculations are to be submitted which may be based on elastic analysis or elastoplastic design methods, *see also* 4.16.11.

4.16.10 Accidental flooding of a single hull compartment is to be considered in the design of the unit. As a minimum, the compartments to be addressed are to include those set out in Chapter 3 of the 2009 IMO MODU Code as applicable to the unit type. Special consideration will be given to unit types not addressed by the 2009 IMO MODU Code.

4.16.11 Units with slender members where the failure of a single member could result in the overall collapse of the unit's structure are to be considered for credible failure of such members, *see* Chapter 4.

4.16.12 Requirements for helicopter landing areas are given in Ch 6,5.

4.16.13 Permissible stresses for accidental load conditions are given in Ch 5,2.

4.16.14 When a National Administration in the country in which the unit is registered and/or in which it is to operate has additional requirements for accidental loads these are to be taken into account in the design loadings.

4.17 Fatigue design

4.17.1 Fatigue damage due to cyclic loading must be considered in the design of all unit types.

4.17.2 Fatigue design calculations are to be carried out in accordance with the analysis procedures and general principles given in Ch 5,5 or other acceptable method.

4.17.3 The factors of safety on calculated fatigue life are to comply with Ch 5,5, but for the hull structure of surface type units, *see* Ch 4,4.

4.18 Other loads

4.18.1 If attending ships/units are to be moored to the unit, the forces imposed by the moorings on the structure are to be taken into account in the design.

4.18.2 Other local loads imposed on the structure by equipment and mooring and towing systems are to be considered in the design of the structure.

4.18.3 When partial filling of tanks is contemplated in operating conditions, the risk of significant loads due to sloshing induced by any of the vessel motions is to be considered. An initial assessment is to be made to determine whether or not a higher level of sloshing investigation is required, using the procedure given in Pt 3, Ch 3,5 of the Rules for Ships.

■ *Section 5*
Number and disposition of bulkheads

5.1 General

5.1.1 The number and disposition of watertight bulkheads are to be arranged to ensure adequate strength and the arrangements are to suit the requirements for subdivision, floodability and damage stability. They are also to be in accordance with the requirements of the National Administration in the country in which the unit is registered and/or in which it is to operate, *see* Pt 1, Ch 2,1 and Chapter 7.

5.1.2 Bulkheads are to be spaced at reasonable uniform intervals. Where, due to the design of a unit, the spacing of bulkheads is unusually great, the transverse strength of the unit is to be maintained by fitting suitable web frames between the bulkheads. Details of bulkheads and intermediate web frames are to be submitted for approval.

5.1.3 The requirements of 5.3.3 are to be complied with as applicable.

5.2 Self-elevating units

5.2.1 The arrangement of longitudinal and transverse bulkheads are to satisfy the overall strength requirements given in Chapters 4 and 5 when the unit is in the elevated position and when afloat.

5.2.2 The number and arrangement of watertight bulkheads are to meet the requirements of damage stability.

5.2.3 Watertight bulkheads are to extend to the uppermost continuous deck.

5.3 Column-stabilised units

5.3.1 The arrangement of watertight bulkheads and flats are to be made effective to that point necessary to meet the requirements of damage stability.

5.3.2 The arrangement of longitudinal and transverse bulkheads in the upper and lower hulls and in columns are to satisfy the overall strength requirements given in Chapters 4 and 5.

5.3.3 The subdivision and arrangement of bulkheads and cofferdams on production and oil storage units are also to comply with Pt 3, Ch 3.

5.4 Protection of tanks carrying oil fuel and lubricating oil

5.4.1 The requirements for the protection of tanks carrying oil fuel and lubricating oil, which are given in Pt 3, Ch 3,4.7 of the Rules for Ships, are to be complied with, as applicable.

Section

■ *Section 1* Column-stabilised units

1.1 General

1.1.1 This Section outlines the structural design requirements of column-stabilised (semi-submersible) units as defined in Pt 1, Ch 2,2. Additional requirements for particular unit types related to the design function of the unit are given in Part 3.

1.1.2 Units which are required to operate while resting on the sea bed are also to comply with the requirements of Section 2.

1.1.3 Production and oil storage units are to comply with the requirements of Pt 3, Ch 3. Columns and pontoons designed for the storage of oil in bulk storage tanks are to be of double hull construction. If pontoon oil storage tanks are always kept empty in transit conditions, a double bottom need not be fitted, except where a double bottom is required by a National Administration.

1.1.4 If it is intended to dry-dock the unit, the bottom structure is to be suitably strengthened to withstand the loadings involved. The proposed docking arrangement plan and maximum bearing pressures are to be submitted.

1.2 Air gap

1.2.1 In all floating modes of operation, column-stabilised units are normally to be designed to have a clearance 'air gap' between the underside of the upper hull deck structure and the highest predicted design wave crest. Reasonable clearance is to be maintained at all times, taking into account the predicted motion of the unit relative to the surface of the sea. Calculations, model test results or prototype reports are to be submitted for consideration.

1.2.2 In cases where the unit is designed without a clearance air gap, the scantlings of the upper hull deck structure are to be designed for wave impact forces, *see also* 1.4.4.

1.3 Structural design

1.3.1 The general requirements for structural design are given in Chapter 3, but the additional requirements of this Section are to be complied with.

1.3.2 The structure is to be designed to withstand the static and dynamic loads imposed on the unit in transit and semi-submerged conditions. All relevant loads as defined in Chapter 3 are to be considered and the permissible stresses due to the overall and local load effects are to be in accordance with Chapter 5. The minimum local scantlings of the unit are to comply with Chapter 6.

1.3.3 All modes of operation are to be investigated and the relevant design load combinations defined in Ch 5,1.2 are to be complied with. The loading conditions applicable to a column-stabilised unit are shown in Table 4.1.1.

Table 4.1.1 Design loading conditions

Mode	Applicable loading condition			
	(a)	(b)	(c) *See* Note 2	(d) *See* Note 2
Operating	✓	✓	✓	✓
Survival	✓	✓	✓	✓
Transit	✓	✓	✓	✓

NOTES
1. For definition of loading conditions (a) to (d), *see* Ch 3,4.3.
2. For loading conditions (c) and (d) as applicable to a column-stabilised unit, *see* 1.3.5 to 1.3.7.

1.3.4 The overall strength of the unit is to be analysed by a three-dimensional finite element method in accordance with Ch 3,3.

1.3.5 In order to ensure adequate structural redundancy after credible failure or accidents, the structure is to be investigated for loading condition (d) in Table 4.1.1. The environmental loads for this load case are to be taken as the same as determined for loading condition (b). The structure is to be able to withstand the following failures without causing the overall collapse of the unit's structure:
- The failure of any main primary bracing member.
- When the upper hull structure consists of heavy or box girder construction, the failure of any primary slender member.

1.3.6 The general requirements for investigating accidental loads are defined in Ch 3,4.16, but in the case of a column-stabilised unit, collision loads against a column or pontoon will normally only cause local damage to the structure and consequently loading condition (c) in Table 4.1.1 need not be investigated from the overall strength aspects. The requirements for very slender columns will be specially considered.

1.3.7 The permissible stress levels after credible failures or accidents are to be in accordance with Chapter 5.

1.4 Upper hull structure

1.4.1 Decks and supporting grillage structures forming part of the primary structure are to be designed to resist both the overall and local loadings.

1.4.2 Openings in primary bulkheads and decks are normally to be represented in the structural model. Bulkhead openings in 'tween decks are not, in general, to be fitted in the same vertical line. When large bulkhead openings are cut in the structure which were not included in the structural model, the bulkhead thickness is to be increased in way of the opening to compensate for the loss of shear area and stiffness.

1.4.3 When the primary deck structure consists of heavy or box girder construction and the infill deck plating is considered to be secondary structure, only the main deck girders and the secondary deck plating stiffeners need satisfy the buckling strength requirements given in Chapter 5. The infill deck plating thickness and its contribution to the overall strength of the structure will be specially considered, *see also* Ch 6,4.

1.4.4 When the upper hull structure is designed to be waterborne for operational purposes the upper hull scantlings are not to be less than those specified for shell boundaries of self-elevating units as defined in Ch 6,3.

1.4.5 Columns should be aligned and integrated with the bulkheads in the upper hull structure. Particular attention should be given to the detail design at the intersection of columns with the upper hull structure to minimise stress concentrations.

1.5 Columns

1.5.1 Columns are to be designed to withstand the forces and moments resulting from the overall loadings, together with forces and moments due to wave loadings and internal tank pressures.

1.5.2 In general, internal spaces within the columns are to be designed for the pressure heads defined in Ch 3,4.14.

1.5.3 High local loads are also to be taken into account in the overall design strength of the columns.

1.5.4 Internal column structure supporting main bracings is in general not to be of a lesser strength than the bracing itself.

1.5.5 When bracing forces are designed to be transmitted to the column shell, the resulting column shell stresses are to be combined with the stresses due to the hydrostatic pressure and overall forces.

1.6 Lower hulls

1.6.1 Lower hulls or pontoons are to be designed for overall bending, shear forces, and axial forces due to end pressure when combined with the local hydrostatic pressure as defined in Ch 3,4.14.

1.6.2 Irrespective of the tank loading arrangement, the scantlings of tanks are to be verified in both full and empty conditions.

1.6.3 Columns are, as far as practicable, to be continuous through the plating of the lower hull deck structure and be aligned and integrated with the internal bulkheads and/or side shell.

1.6.4 Where the column shell plating is intercostal with the lower hull deck, the deck plating below the columns is to be suitably increased and is to have steel grades with suitable through-thickness properties, *see* Ch 2,4.1.3.

1.6.5 Particular attention should be given to the design of the local structure at the intersection of columns with lower hulls and due account should be given to penetrations and stress concentrations.

1.7 Main primary bracings

1.7.1 Bracing members are to be designed to withstand the stresses imposed by the overall loading, together with local stresses due to wave, current and buoyancy forces and, when applicable, hydrostatic pressure.

1.7.2 Bracings are in general to be made watertight and provided with adequate means of access to enable internal inspection to be carried out when the unit is afloat.

1.7.3 Watertight bracings are to be designed for the hydrostatic pressure loads defined in Ch 3,4.14, and the scantlings are to be verified against buckling due to combined axial stresses and hoop stresses caused by external hydrostatic pressure. Ring stiffeners are to be fitted where necessary.

1.7.4 Attachments and penetrations to the shell of bracings are to be avoided as far as practicable. If attachments are unavoidable they are generally to be welded to suitable doubler plates having well rounded corners. Special consideration will be given to alternative proposals. In all cases the attachment is to be designed to minimise the resulting stress concentration in the brace and the fatigue life is to be checked.

1.7.5 Leak detection and drainage arrangements of watertight bracings are to be in accordance with Pt 5, Ch 13,3.

1.7.6 The scantlings and arrangements of free-flooding bracings will be specially considered.

1.8 Bracing joints

1.8.1 Joints at the intersection of bracings or between bracings and columns are to be designed to transmit the bending, direct and shear forces involved in such a manner as to reduce, so far as possible, the risk of fatigue failure. Stress concentrations are to be minimised by good detail design and, in general, nominal stress levels are to be made lower than in the adjacent structure by increasing plate thickness or suitably flaring the member ends, or both. Ring stiffeners or other welded attachments across the principal stress direction are to be avoided wherever possible in all regions of high stress. It this is not possible (e.g. where required to support bracket ends on otherwise unstiffened plating), the weld is to have a smooth profile without undercutting. Continuity of strength is to be maintained through the joint, and shear web plates and other axial stiffening members are to be made continuous.

1.8.2 Special attention is also to be given to the qualities of bracing details, e.g., openings, penetrations, stiffener ends, brackets and other attachments. The welding procedure is to be such as to minimise the risk of cracks, lack of penetration and lamellar tearing of the parent steel.

1.8.3 Joints depending upon transmission of tensile stresses through the thickness of the plating of one of the members (which may result in lamellar tearing) are to be avoided wherever possible. Plate steel used in such locations shall have suitable through-thickness properties.

1.9 Lifeboat platforms

1.9.1 The strength of lifeboat platforms is to be verified with the unit in the upright condition and in the inclined condition at an angle corresponding to the worst damage waterline, and at an inclined angle of 15° in any direction.

1.9.2 For calculation purposes, the weight of the lifeboat is to be taken as the weight when fully manned and equipped. The platform weight is to be taken as the steel weight plus the weight of davits and equipment. Symmetrical and unsymmetrical load cases are to be considered as appropriate, e.g. one lifeboat launched and the other lowering. The design calculations are to be submitted for information.

1.9.3 The following dynamic load factors are to be included in the calculations:

Item:	Factor:
Platform weight	0,3 g
Lifeboat weight when stowed	0,3 g
Lifeboat weight when lowering	0,5 g

1.9.4 In the upright condition and in the inclined condition the permissible stresses are to comply with Ch 5,2.1.1, loadcase (a) and (b) respectively.

1.9.5 After installation of the lifeboats, testing is to be carried out to the satisfaction of LR's Surveyors.

1.10 Topside structure

1.10.1 The minimum scantlings of superstructures and deckhouses are to comply with the requirements of Ch 6,9. Bulwarks and guard rails are to comply with Ch 6,10.

1.10.2 For units fitted with a process plant facility and/or drilling equipment, the support stools and integrated hull support structure to the process plant and other equipment supporting structures including derricks and flare structures are considered to be classification items, regardless of whether or not the process/drilling plant facility is classed, and the loadings are to be determined in accordance with Pt 3, Ch 8,2. Permissible stress levels are to comply with Chapter 5.

1.10.3 The boundary bulkheads of accommodation spaces which may be subjected to blast loading are to be designed in accordance with Ch 3,4 and permissible stress levels are to satisfy the factors of safety given in Ch 6,2.1.1(c).

1.10.4 Units with a process plant facility which comply with the requirements of Pt 3, Ch 8 will be eligible for the assignment of the special features class notation **PPF**.

1.10.5 Units with a drilling plant facility which comply with the requirements of Pt 3, Ch 7 will be eligible for the assignment of the special features class notation **DRILL**.

■ *Section 2* Sea bed-stabilised units

2.1 General

2.1.1 This Section outlines the structural design requirements of sea bed-stabilised units as defined in Pt 1, Ch 2,2. Additional requirements for particular unit types related to the design function of the unit are given in Part 3. Self-elevating units are to comply with Section 3.

2.1.2 Units of this type are generally designed to operate under normal operating environmental conditions and severe storm conditions whilst resting on the sea bed. The design transit condition and design limitations are to be specified by the Owner/designer.

2.1.3 The structural analysis and determination of scantlings is to be on the basis of distribution of loadings and ballast required to satisfy 2.1.2 and all units are to have adequate reserve of bearing pressure on the support footings, pontoons or mats.

2.1.4 The requirements of Sections 1 and 3 are to be complied with as applicable to the design of the unit.

2.1.5 The permissible stress levels in all operating modes are to comply with Chapter 5.

2.1.6 The minimum local scantlings are to comply with the requirements of Chapter 6, for column-stabilised units as applicable, but the bottom structure should not be less than required for tank bulkheads in Chapter 6 using the load head h_4 equivalent to the maximum design bearing pressure. In general, bottom primary members supporting shell stiffeners are to be spaced not more than 1,85 m apart and side girders or equivalent are to be spaced 2,2 m apart. The buckling strength of the primary member webs is to be in accordance with Chapter 5, *see also* 2.4.

2.2 Air gap

2.2.1 For on-bottom modes of operation, the clearance air gap between the underside of the deck structure and the highest predicted design wave crest is to be in accordance with 3.2.1. In transit conditions, the air gap is to be in accordance with 1.2. Calculations, model test results or prototype reports are to be submitted for consideration.

2.3 Operating conditions

2.3.1 Classification will be based upon the Owner's/ designer's assumptions in operating the unit and the sea bed conditions. These assumptions are to be recorded in the Operations Manual. It is the responsibility of the Operator to ensure that actual conditions do not impose more severe loadings on the unit.

2.3.2 Procedures and limitations for ballasting and re-floating the unit in order to avoid overstressing the structure by static or dynamic loads are to be clearly defined in the Operations Manual, *see* Pt 3, Ch 1,3.

2.4 Corrosion protection

2.4.1 The corrosion allowance for wastage and the means of protection are to be to the satisfaction of LR and are to be agreed at the design stage.

2.4.2 The general requirements for corrosion protection are to comply with Part 8.

■ *Section 3* Self-elevating units

3.1 General

3.1.1 This Section outlines the structural design requirements of self-elevating units. Additional requirements for particular unit types related to the design function of the unit are given in Part 3.

3.1.2 A self-elevating unit is a floating unit which is designed to operate as a sea bed-stabilised unit in an elevated mode, *see* Pt 1, Ch 2,2.

3.1.3 Production units are to comply with the requirements of Pt 3, Ch 3 as applicable.

3.1.4 The structural analysis and determination of primary scantlings are to be on the basis of the distribution of loadings expected in all modes of operation.

3.2 Air gap

3.2.1 When in the elevated position, the unit is to be designed to have a clearance air gap between the underside of the hull structure and the highest predicted design wave crest superimposed on the maximum surge height over the maximum mean astronomical tide. The minimum clearance is not to be less than 1,5 m. Calculations, model test results or prototype reports are to be submitted for consideration.

3.3 Structural design

3.3.1 The structure is to be designed to withstand the static and dynamic loads imposed upon it in transit, installation and elevated conditions. All relevant distributions of gravity and variable loads are to be considered, as are stresses due to the overall and local effects, *see* Ch 3,4.

3.3.2 The permissible stresses are to be in accordance with Chapter 5 and the minimum local scantlings of the unit are to comply with Chapter 6.

3.3.3 All modes of operation are to be investigated and the relevant design load combinations defined in Ch 5,1.2 are to be complied with. The loading conditions applicable to a self-elevating unit are shown in Table 4.3.1.

Table 4.3.1 Design loading conditions

Mode	Applicable loading condition			
	(a)	(b)	(c) *See* Note 2	(d) *See* Note 2
Site installation and re-floating		✓		
Operating	✓	✓	✓	✓
Survival	✓	✓	✓	✓
Transit	✓	✓	✓	✓

NOTES
1. For definition of loading conditions (a) to (d), *see* Ch 3,4.3.
2. For loading conditions (c) and (d) as applicable to a self-elevating unit, *see* 3.3.4 to 3.3.6.

3.3.4 The general requirements for investigating accidental loads are defined in Ch 3,4.16. In transit conditions, collision loads against the hull structure will normally only cause local damage to the hull structure and consequently loading condition (c) in Table 4.3.1 need not be investigated from the overall strength aspects. When in the elevated position, accidental damage to the legs is to be considered in the design and the unit is to be capable of absorbing the energy of impact in association with environmental loads corresponding to the appropriate one year storm condition.

3.3.5 In general, for loading condition (c) in Table 4.3.1, the level of impact energy absorbed by the local leg structure is not to be taken less than 2 MJ. If the unit is only to operate in protected waters, as defined in Pt 1, Ch 2,2.4, the level of impact energy absorbed by the local leg structure may be reduced but should not be less than 0,5 MJ. Collision loads will, in general, only cause local damage to one leg, but the possibility of progressive collapse and overturning should be considered in the design calculations which should be submitted for consideration.

3.3.6 The permissible stress levels after credible failures or accidents are to be in accordance with Chapter 5.

3.3.7 Fatigue damage due to cyclic loading is to be considered in the design of the legs of the unit for transit and elevated conditions. Fatigue damage is considered accumulative throughout the unit's design life. The extent of the fatigue analysis will be dependent on the mode and area of operations, *see* Ch 5,5.

3.4 Hull structure

3.4.1 The hull is to be considered as a complete structure having sufficient strength to resist all induced stresses while in the elevated position and supported by its legs. All fixed and variable loads are to be distributed, by an accepted method of rational analysis, from the various points of application to the supporting legs. The scantlings of the hull are then to be determined consistent with this load distribution.

3.4.2 Due account must be taken of loadings induced in the transit condition from external sea heads, variable deck loads and legs.

3.5 Deckhouses

3.5.1 Deckhouses are to have sufficient strength for their size, function and location. Requirements for scantlings are given in Ch 6,9.

3.5.2 Special consideration is to be given to the scantlings of deckhouses and deck modules which will not be subjected to wave loading in any operating condition such as units which are 'dry-towed' to the operating location.

3.6 Structure in way of jacking or elevating arrangements

3.6.1 Load carrying members in the jackhouses and frames which transmit loads between the legs and the hull are to be designed for the maximum design loads and are to be so arranged that loads transmitted from the legs are properly diffused into the hull structure. The scantlings of jackhouses are not to be less than required for deckhouses in accordance with Ch 6,9.

3.7 Leg wells

3.7.1 The scantlings and arrangements of the boundaries of leg wells are to be specially considered and the structure is to be suitably reinforced in way of leg guides, taking into account the maximum forces imposed on the structure. The minimum scantlings of leg wells are to comply with Ch 6,3.3.

3.8 Leg design

3.8.1 Legs may be either shell type or lattice type. Independent footings may be fitted to the legs or legs may be permanently attached to a bottom mat. Shell type legs may be designed as either stiffened or unstiffened shells.

3.8.2 Where legs are fitted with independent footings, proper consideration is to be given to the leg penetration of the sea bed and the end fixity of the leg.

3.8.3 Leg scantlings are to be determined in accordance with a method of rational analysis and calculations submitted for consideration, *see* Ch 3,3.

3.8.4 For lattice legs, the slenderness ratio of the main chord members between joints is not to exceed 40, or two thirds of the slenderness ratio of the leg column as a whole, whichever is the lesser, unless it can be shown that a calculation taking into account beam-column effect, joint rigidity and joint eccentricity justifies a higher figure.

3.9 Unit in the elevated position

3.9.1 When computing leg stresses with the unit in the elevated position, the maximum overturning load and maximum shear load on the unit, using the most adverse combination of applicable variable loadings together with the environmental design loadings, are to be considered with the following criteria:

(a) **Wave forces**: Values of drag coefficient, C_D, and inertia coefficient, C_m, vary considerably with Reynolds number, R_n, and Keulegan-Carpenter number, N_k, and are to be carefully chosen to suit the individual circumstances. In calculating the wave forces using acceptable wave theories, values as given in (i) to (iii) for the hydrodynamic coefficients C_D and C_M, for non-tubular members of the leg chords may be used essentially in the drag dominated regime with post-critical R_n and high N_k. Otherwise more detailed information based on tests or published data is to be used.

(i) Cylindrical chord members with protruding racks:
Drag coefficient,

$$C_D = C_d + \frac{(D_E - D_C)}{D_C} (2 \sin\theta)$$

For marine fouled members, C_D calculated is to be factored by 1,2.
Inertia coefficient,

$$C_M = C_m \left(\frac{A_g}{A_C}\right)$$

where
C_d = the drag coefficient used for a smooth cylinder member
C_m = the inertia coefficient used for a cylinder member
D_E = pitch distance of the racks
D_C = nominal diameter of the cylindrical part of the member
A_g = the cross-sectional area of the member
A_c = the cross-sectional area of the cylindrical part of the member
= the angle between the flow direction and the central line of the cross-section along the racks

(ii) Triangular chord members:
Drag coefficient, for smooth triangular members:
C_D = 1,6 θ = 0°
C_D = 1,4 θ = 45°
C_D = 1,8 θ = 90°
C_D = 1,7 θ = 135°
C_D = 1,3 θ = 180°
For marine fouled members, the C_D values are to be factored by 1,2.
Inertia coefficient, C_M = 1,4
where
θ = Relative approach angle of flow, 0° being towards the backplate and to be counted clockwise.

(iii) Other shapes of non-tubular members: C_D, C_M values should be assessed based on the relevant published data or appropriate tests. The tests should consider possible roughness, Keulegan-Carpenter and Reynolds numbers dependence.

(b) **Dynamics**: Due account of dynamics is to be taken in computing leg stresses when this effect is significant. The following governing aspects are to be included:
(i) The mass and mass distribution of the unit. This includes structural mass, mass of equipment and variable load on board, added mass due to the surrounding water and marine growth, if applicable, etc.
(ii) The global unit structural stiffness. This includes stiffness contributions from the leg to hull connections and the footing interface, if applicable.
(iii) The damping. This includes structural damping, foundation damping and hydrodynamic damping.

(c) **Other considerations**: Other considerations in computing leg stresses include:
(i) Forces and moments due to initial leg inclination and lateral frame deflections of the legs.
(ii) Bending moments at leg/hull connections due to hull sagging under gravity loads.

3.10 Legs in field transit conditions

3.10.1 In field transit conditions within the same geographical area, legs are to be designed for acceleration forces caused by a 6° single amplitude of roll or pitch at the natural period of the unit, plus, 120 per cent of the gravity forces caused by the legs' angle of inclination, unless otherwise verified by appropriate model tests or calculations. The legs are to be investigated for any proposed leg arrangement with respect to vertical position during field transit moves, and the approved positions are to be specified in the Operations Manual. Such investigation is to include strength and stability aspects. Field transit moves may only be undertaken when the predicted weather is such that the anticipated motions of the unit will not exceed the design condition.

3.10.2 The duration of a field transit move may be for a considerable period of time and should be related to the accuracy of weather forecasting in the area concerned. It is recommended that such a move should not normally exceed a twelve hour voyage between protected locations or locations where the unit may be safely elevated. However, during any portion of the move, the unit should not normally to be more than a six hour voyage to a protected location or a location where the unit may be safely elevated. Suitable instructions are to be included in the Operations Manual. Where a special leg position is required for field moves, this position is to be specified in the Operations Manual.

3.11 Legs in ocean transit conditions

3.11.1 In ocean transit conditions involving a move to a new geographical area, legs are to be designed for acceleration and gravity loadings resulting from the motions in the most severe anticipated environmental transit conditions, together with corresponding wind moments. Calculation or model test methods may be used to determine the motions. Alternatively, legs may be designed for the acceleration and gravity forces caused by a design criterion of 20° single amplitude of roll or pitch at a 10 second period. For ocean transit conditions, it may be necessary to reinforce or support the legs, or to remove sections of them. The approved condition is to be included in the Operations Manual.

3.12 Legs during installation conditions

3.12.1 When lowering the legs to the sea bed, the legs are to be designed to withstand the dynamic loads which may be encountered by their unsupported length just prior to touching the sea bed and also to withstand the shock of touching bottom while the unit is afloat and subject to wave motions.

3.12.2 Instructions for lowering the legs are to be clearly indicated in the Operations Manual. The maximum design motions, bottom conditions and sea state while lowering the legs are to be clearly stated. The legs are not to be lowered in conditions which may exceed the design criteria.

3.12.3 For units without bottom mats, all legs are to have the capability of being preloaded to the maximum applicable combined gravity plus overturning load. The approved preload procedure should be included in the Operations Manual.

3.12.4 Consideration is to be given to the loads caused by a sudden penetration of one or more legs during preloading.

3.13 Stability in-place

3.13.1 When the legs are resting on the sea bed, the unit is to have sufficient positive downward gravity loadings on the support footings or mat to withstand the overturning moment of the combined environmental forces from any direction, with a reserve against the loss of positive bearing of any footing or segment of the area, for each design loading condition. The most critical minimum variable load condition is to be considered for each loading direction and in no case is the variable load to be taken greater than 50 per cent of the maximum and using the least favourable location of the centre of gravity.

3.13.2 The safety factor against overturning is to be at least 1,25 with respect to the rotational axis through the centres of the independent footings at the sea bed. For a unit with a mat type footing, the rotational axis is to be taken at the maximum stressed edge of the mat.

3.13.3 For independent footings, the safety factor against sliding at the sea bed is to be related to the soil condition, but in no case is the safety factor to be taken as less than 1,0.

3.14 Sea bed conditions

3.14.1 Classification will be based upon the designer's assumptions regarding the sea bed conditions. These assumptions are to be recorded in the Operations Manual.

3.14.2 Full details of the sea bed at the operating location are to be submitted to LR for review at the design stage. The effects of scouring on bottom mat bearing surfaces and footings is to be considered, *see* 3.16.3.

3.15 Foundation fixity

3.15.1 For units with independent legs, foundation fixity should not normally be considered for in-place strength analysis of the upper parts of the leg in way of the lower guides unless justified by proper investigation of the footing and soil conditions.

3.15.2 For in-place analysis, the lower parts of the leg with independent footings are to be designed for a leg moment no less than 50 per cent of the maximum leg moment at the lower guides, together with the associated horizontal and vertical loads.

3.16 Bottom mat

3.16.1 When the legs are attached to a bottom mat, the scantlings of the mat are to be specially considered, but the permissible stress levels are to be in accordance with Chapter 5. Particular attention is to be given to the attachment, framing and bracing of the mat in order that the loads from the legs are effectively distributed into the mat structure.

3.16.2 Mats and their attachments to the bottom ends of the legs are to be of robust construction to withstand the shock load on touching the sea bed while the unit is afloat and subject to wave motions.

3.16.3 The effects of scouring on the bottom bearing surfaces should be considered by the designer, with a stated design figure for loss of bearing area. The effects of skirt plates, where provided, may be taken into account, *see also* 3.14.1.

3.16.4 The minimum local scantlings of the mat structures are to comply with 3.17.5 and 3.17.6.

3.17 Independent footings

3.17.1 Independent footings are to be designed to withstand the most severe combination of overall and local loadings to which they may be subjected, *see also* 3.16.3. In general, the primary structure is to be analysed by a three-dimensional finite element method.

3.17.2 The complexity of the mathematical model together with the associated element types is to be sufficiently representative of all parts of the primary structure to enable internal stress distributions to be established.

3.17.3 The loading combinations considered are to represent all modes of operation so that the critical design cases are established, and are to include, but not be limited to, the following:

(a) The maximum preload concentrated or distributed over the area of initial contact.
(b) The maximum preload uniformly distributed over the entire bottom area.
(c) The relevant preload distributed over contact areas corresponding to intermediate levels of penetration, as required.
(d) The greatest leg load due to the specified environmental maxima applied over the entire bottom area, with the pressure varying linearly from zero at one end to twice the mean value at the other end.
(e) The distribution in (d) applied in different directions, depending on structural symmetry, to cover all possible wave headings.
(f) Where it is intended to move the unit without the footings being fully retracted, a special analysis of the leg to spudcan connections may be required.

3.17.4 The permissible stresses are to be based on the safety factors for yield and buckling as defined in Ch 5,2. The preload cases may be considered as load case (a) in Ch 5,2 while the loadings associated with the maximum storm cases may be taken as load case (b) in Ch 5,2.

3.17.5 The minimum local scantlings of the bottom shell and stiffening and other areas subjected to pressure loading are to be determined from the formulae for tank bulkheads given in Ch 6,7. The loadhead h_4 should be consistent with the maximum bearing pressure, determined in accordance with 3.17.3, and the wastage allowance of the plating should be not less than 3,5 mm, *see also* 3.17.6.

3.17.6 Where it is intended to operate at a fixed location for the design life of the unit, the footing/leg structure which is below the mud line or internal areas of the footings which cannot be inspected are to have their structure designed with adequate corrosion margins and protection. The corrosion allowance for wastage and the means of protection are to be to the satisfaction of LR and are to be agreed at the design stage.

3.17.7 When the structure consists of compartments which are not vented freely to the sea, the scantlings of the shell boundaries and stiffening are not to be less than required for tank boundaries in Ch 6,7 using the load head h_4 not less than 1,4T_0 m, where T_0 is defined in Ch 1,5.

3.17.8 Where the legs of the unit are made from steel with extra high tensile strength, special consideration is to be given to the weld procedures for the leg to footing connections. Adequate preheat should be used and the cooling rate should be controlled. Any non-destructive examination of the welds should be carried out after a minimum of 48 hours have elapsed after the completion of welding.

3.18 Lifeboat platforms

3.18.1 When self-elevating units are fitted with cantilevered lifeboat platforms, the strength of the platforms is to comply with 1.9. If the lifeboat platform can be subjected to wave impact forces in transit conditions, the scantlings are to be specially considered and details are to be submitted for consideration by LR.

3.19 Topside structure

3.19.1 General requirements for topside structure are given in 1.10.

■ *Section 4* Surface type units

4.1 General

4.1.1 This Section outlines the hull structural design requirements of ship and barge type units engaged in drilling and support activities.

4.1.2 Units which operate as shuttle oil tankers will be assigned class in accordance with the Rules for Ships.

4.1.3 In general, hull strength, scantlings and arrangements for surface type units are to comply with the relevant requirements of the Rules for Ships as applicable to the service of the unit.

4.1.4 All aspects which relate to the specialised offshore function of the unit are to be considered on the basis of these Rules, *see also* Pt 3 Ch 1. Additional requirements related to the design arrangements and function of drilling and production units given in Pt 3, Ch 2 and Ch 3 are to be complied with.

4.1.5 **Drilling well/Moonpool**. The hull structure in way of the drilling well is to be suitably strengthened so as to ensure continuity of the required longitudinal strength.

4.1.6 **Structural analysis**. For surface type units, the strength of primary structures of hull compartments and of deck supporting structures, including longitudinal and transverse bulkheads, is to be assessed in accordance with relevant LR *ShipRight* SDA Procedures.

4.1.7 **Fatigue design**. Fatigue damage due to cyclic loading is to be considered. The nature and extent of the fatigue analysis will depend on the mode and area of operation. For details of the fatigue required analyses, *see* Ch 5,5.

4.1.8 The scantlings and arrangements of units with a limited number of tanks for bulk storage of flammable liquids having a flash point not exceeding 60°C (closed-cup test) will be specially considered. Double hull construction in bulk oil tank storage regions will normally be required, *see also* Pt 3, Ch 3.

4.1.9 Additional requirements related to the design function of the unit are given in Part 3.

■ *Section 1* General requirements

1.1 General

1.1.1 This Section defines the overall strength requirements of the unit and the permissible stresses in all operating modes.

1.1.2 The design loads are to be in accordance with Ch 3,4 and the design conditions are to be based on the most unfavourable combinations of gravity loads, functional loads, environmental loads and accidental loads.

1.1.3 Specific requirements for structural unit types are also defined in Chapter 4.

1.1.4 The local strength of the unit is to comply with the requirements of Chapter 6.

1.1.5 The limiting design environmental and operational conditions for each mode of operation is to be defined by the Owner/designer and included in the Operations Manual, *see* Pt 3, Ch 1,3.

1.2 Structural analysis

1.2.1 A structural analysis of the primary structure of the unit is to be carried out in accordance with the requirements of Chapter 3 and the resultant stresses determined.

1.2.2 The loading conditions are to represent all modes of operation and the critical design cases obtained.

1.2.3 The structure is to be analysed for the relevant load combinations given in Ch 3,4.3.

1.2.4 For the combined load cases applicable to all unit types, *see also* Chapter 4.

1.2.5 The permissible stress levels relevant to the combined load cases defined in 1.2.3 are to be in accordance with Section 2.

1.2.6 Special consideration is to be given to structures subjected to large deformations.

1.3 Primary structure

1.3.1 Local stresses, including those due to circumferential loading on tubular members, are to be added to the primary stresses to determine total stress levels.

1.3.2 The scantlings are to be determined on the basis of criteria which combine, in a rational manner, the individual stress components acting on the various structural elements of the unit. The stresses are to be determined using net scantlings, i.e., no corrosion allowance included, *see also* Pt 3, Ch 1,5.

1.3.3 The critical buckling stress of structural elements is to be considered in relation to the computed stresses, *see* Sections 3 and 4.

1.3.4 Fatigue damage due to cyclic loading is to be considered in the design of the unit in accordance with Section 5.

1.3.5 When computing bending stresses, the effective flange areas are to be determined in accordance with 'effective width', concepts derived from accepted shear lag theories and plate buckling considerations.

1.3.6 Where appropriate, elastic deflections are to be taken into account when determining the effects of eccentricity of axial loading, and the resulting bending moments superimposed on the bending moments computed for other types of loadings.

1.3.7 When computing shear stresses in bulkheads, plate girder webs or hull side plating, only the effective shear area of the plate or web is to be considered. For girders, the total depth of the girder may be considered as the web depth.

1.3.8 Members of lattice type structures may be designed in accordance with a recognised Code as defined in Part 3, Appendix A.

1.4 Connections and details

1.4.1 Special consideration is to be given to structural continuity and connections of critical components of the primary and special structure, such as the following:

- Bracing intersections and end connections.
- Columns to lower and upper hulls.
- Jackhouses to deck.
- Legs to mat or footings.
- Mooring line attachments.

1.4.2 Critical joints depending upon the transmission of tensile stresses through the thickness of the plating of one of the members which may result in lamellar tearing are to be avoided wherever possible, *see* Ch 2,4.1.3.

1.4.3 Welding and structural details are to be in accordance with Chapter 8.

1.5 Stress concentration

1.5.1 The effect of notches, stress raisers and local stress concentrations is to be taken into account in the design of load-carrying elements.

■ *Section 2* **Permissible stresses**

2.1 General

2.1.1 For the combined load cases, as defined in Ch 3,4.3, the maximum permissible stresses of steel structural members are to be based on the following factors of safety unless otherwise specified:

(a) Load case (a):
- 2,50 for shear (based on the tensile yield stress)
- 1,67 for shear buckling (based on the shear buckling stress)
- 1,67 for tension and bending (based on the tensile yield stress)
- 1,67 for compression (based on the lesser of the least buckling stress or the yield stress)
- 1,43 for combined 'comparative' stress (based on the tensile yield stress).

(b) Load case (b) and (c):
- 1,89 for shear (based on the tensile yield stress)
- 1,25 for shear buckling (based on the shear buckling stress)
- 1,25 for tension and bending (based on the tensile yield stress)
- 1,25 for compression (based on the lesser of the least buckling stress or the yield stress)
- 1,11 for combined 'comparative' stress (based on the tensile yield stress).

(c) Load case (d):
- 1,72 for shear (based on the yield stress)
- 1,0 for shear buckling (based on the shear buckling stress)
- 1,0 for tension and bending (based on the tensile yield stress)
- 1,0 for compression (based on the lesser of the least buckling stress or the yield stress)
- 1,0 for combined 'comparative' stress (based on the tensile yield stress).

2.1.2 For plated structures, the combined 'comparative' stress is to be determined where necessary from the formula:

$$\sigma_{cc} = \sqrt{\sigma_x{}^2 + \sigma_y{}^2 - \sigma_x\sigma_y + 3\tau^2}$$

where σ_x and σ_y are the combined axial and bending stresses in the X and Y directions respectively, τ is the combined shear stress due to torsion and/or bending in the X-Y plane.

2.1.3 When finite element methods are used to verify scantlings, special consideration will be given to areas of the structure where localised peak stresses occur.

2.1.4 Non linear and plastic design methods may be used for verifying the local structure in load cases (c) and (d), as defined in Ch 3,4.3. Local yielding and permanent deformation can be accepted; however, the structural arrangements must prevent progressive collapse.

2.1.5 The buckling strengths of plates and stiffeners are to comply with Section 3.

2.1.6 The buckling strength for individual primary members subjected to axial compression and combined axial compression and bending is to be in accordance with Section 4.

2.1.7 Permissible stress levels for lattice type structures are to be determined as required by 1.3.8.

2.1.8 Permissible stresses in materials other than steel are to be specially considered.

■ *Section 3* **Buckling strength of plates and stiffeners**

3.1 Application

3.1.1 The requirements of this Section apply to plate panels, and attached stiffeners subject to overall hull structure compression and shear stresses. The maximum design values computed are to be determined in accordance with 1.2.

3.1.2 For states of stress which cannot be defined by one single reference stress, the buckling characteristics are to be based on recognised interaction formulae.

3.1.3 LR's ShipRight program no. 10206 may be used for the buckling assessment of flat rectangular plate panels by direct calculation.

3.2 Symbols

3.2.1 The symbols used in this Section are defined as follows:

E = modulus of elasticity, in N/mm^2 (kgf/mm^2)
 = 206 000 N/mm^2 (21 000 kgf/mm^2) for steel

σ_o = specified minimum yield stress, in N/mm^2 (kgf/mm^2)

σ_{CRB} = critical buckling stress in compression, in N/mm^2 (kgf/mm^2), corrected for yielding effects

σ_E = elastic critical buckling stress in compression, in N/mm^2 (kgf/mm^2)

τ_{CRB} = critical buckling stress in shear, in N/mm^2 (kgf/mm^2), corrected for yielding effects

τ_E = elastic critical buckling stress in shear, in N/mm^2 (kgf/mm^2)

$$\tau_o = \sqrt{\frac{\sigma_o}{3}}$$

3.3 Elastic critical buckling stress

3.3.1 The elastic critical buckling stress of plating and stiffeners is to be determined in accordance with an agreed Code or Standard or according to Table 4.7.2 and Table 4.7.3 in Pt 3, Ch 4,7, of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships).

3.4 Scantling criteria

3.4.1 The critical buckling stress in compression, corrected for yielding effects, σ_{CRB}, of plate panels and stiffeners, as derived from Table 4.7.2 and Table 4.7.3 in Pt 3, Ch 4,7 of the Rules for Ships, is to satisfy the following:

$$\sigma_{CRB} \geq F_{SC}\ \sigma_A$$

where
F_{SC} = factor of safety for compression in accordance with 2.1.1 for the appropriate load case.

3.4.2 The critical buckling stress in shear, corrected for yielding effects, τ_{CRB}, of plate panels as derived from Table 4.7.2(c), in Pt 3, Ch 4,7 of the Rules for Ships, is to satisfy the following:

$$\tau_{CRB} \geq F_{SS}\ \tau_A$$

where
F_{SS} = factor of safety for shear buckling in accordance with 2.1.1 for the appropriate load case.

3.4.3 Buckling criteria are to be determined for plating and plate and stiffener combinations, including (but not limited to):

- Flat bar stiffeners.
- Bulb plate stiffeners.
- Rolled angles.
- Built-up profiles.
- Floors or deep girders.

3.4.4 All appropriate buckling modes are to be investigated, including:

- Column buckling.
- Torsional buckling.
- Web and flange buckling.

3.4.5 In general, stresses are to be determined using net scantlings, i.e., no corrosion allowance included.

Section 4
Buckling strength of primary members

4.1 Application

4.1.1 The requirements of this Section are applicable to individual primary structural members which are subjected to axial compression or combined axial compression and bending due to overall loading.

4.2 Symbols

4.2.1 The symbols used in this Section are defined as follows:

σ_o, E as defined in 3.2.1

σ_A = computed axial compressive stress, in N/mm^2 (kgf/mm^2)

σ_B = computed compressive stress due to bending, in N/mm^2 (kgf/mm^2)

F_A = factor of safety for compression, in accordance with 2.1.1

F_B = factor of safety for bending, in accordance with 2.1.1

F_C = factor of safety for overall member buckling, as determined from Table 5.4.2

σ_{CRB} = critical overall member buckling stress, in N/mm^2 (kgf/mm^2), as determined from Table 5.4.1

σ_C = local member critical buckling stress, in N/mm^2 (kgf/mm^2)

σ_{PA} = permissible axial compressive stress, in N/mm^2 (kgf/mm^2)

$$= \frac{\sigma_o}{F_A} \text{ or } \frac{\sigma_c}{F_A} \text{ or } \frac{\sigma_{CRB}}{F_C} \quad \text{whichever is the lesser}$$

σ_{PB} = permissible compressive stress due to bending, in N/mm^2 (kgf/mm^2)

$$= \frac{\sigma_o}{F_B} \text{ or } \frac{\sigma_c}{F_B} \quad \text{whichever is the lesser}$$

D = mean diameter of cylindrical shell, in mm

t = thickness of cylindrical shell, in mm.

4.3 Elastic critical buckling stress

4.3.1 Where the elastic critical buckling stress exceeds 50 per cent of the specified minimum yield stress of the material, the calculated critical buckling stresses are to be corrected for yielding effects and are given by:

$\sigma_C = \sigma_o\,(1 - \sigma_o/4\sigma_E)$ N/mm^2 (kgf/mm^2) in compression.

4.4 Scantling criteria

4.4.1 Individual members are to be investigated for overall critical buckling in accordance with an agreed Code or Standard or Table 5.4.1 and Table 5.4.2 and also for local buckling.

4.4.2 The local buckling of cylindrical shells, either unstiffened or ring-stiffened, is to be investigated if the proportions of the shell conform to the following:

$$\frac{D}{t} > \frac{E}{9\sigma_o}$$

4.4.3 When individual primary structural members are subjected to axial compression or combined axial compression and bending, the computed design stresses are to satisfy the following requirement:

$$\frac{\sigma_A}{\sigma_{PA}} + \frac{\sigma_B}{\sigma_{PB}} \leq 1{,}0$$

Table 5.4.1 Overall member critical buckling stress

Condition	Member critical buckling stress σ_{CRB}, N/mm^2 (kgf/mm^2)
(a) When $\lambda < \sqrt{\eta}$	$\sigma_o - \dfrac{\sigma_o^2 \lambda^2}{4\pi^2 E}$
(b) When $\lambda \geq \sqrt{\eta}$	$\dfrac{\pi^2 E}{\lambda^2}$
Symbols and parameters	
σ_o, E as defined in 3.2.1 l = unsupported length of member, in metres K = effective length factor to be generally taken as unity but will be specially considered in association with end conditions l_e = Kl = unsupported effective length of member, in metres r = least radius of gyration of member cross-section, in mm, and may be taken as: $r = 10\sqrt{\dfrac{I}{A}}$ mm A = cross-sectional area of member, in cm^2 I = least moment of inertia of member cross-section, in cm^4 λ = slenderness ratio and may be taken as: $\lambda = \dfrac{1000 l_e}{r}$ $\eta = \dfrac{2\pi^2 E}{\sigma_o}$	

Table 5.4.2 Factors of safety for overall member buckling

Condition	Factor of safety, F_C
(1) For case (a) as defined in 2.1.1:	
(a) When $\lambda < \sqrt{\eta}$	$1{,}67 + \dfrac{0{,}25\lambda}{\sqrt{\eta}}$
(b) When $\lambda \geq \sqrt{\eta}$	1,92
(2) For cases (b) and (c) as defined in 2.1.1:	
(a) When $\lambda < \sqrt{\eta}$	$1{,}25 + \dfrac{0{,}19\lambda}{\sqrt{\eta}}$
(b) When $\lambda \geq \sqrt{\eta}$	1,44
(3) For case (d) as defined in 2.1.1:	
(a) When $\lambda < \sqrt{\eta}$	$1{,}0 + \dfrac{0{,}15\lambda}{\sqrt{\eta}}$
(b) When $\lambda \geq \sqrt{\eta}$	1,15
Symbols and parameters	
F_C as defined in 4.2.1 λ and η as defined in Table 5.4.1	

■ *Section 5*
Fatigue design

5.1 General

5.1.1 Fatigue damage due to cyclic loading is to be considered in the design of all unit types. The extent of the fatigue analysis will be dependent on the mode and area of operation.

5.1.2 Where any unit is intended to operate at one location for an extended period of time, a rigorous fatigue analysis is to be performed using the long-term prediction of environment for that area of operation with the unit at the intended orientation. Due allowance is to be made of any previous operational history of the unit.

5.1.3 The two basic methods of fatigue analysis available are Deterministic Fatigue Analysis and Spectral Fatigue Analysis. Both are acceptable to LR.

5.1.4 Factors which influence fatigue endurance and should be accounted for in the design calculations include:

- Loading spectrum.
- Detail structural design.
- Fabrication and tolerances.
- Corrosion.
- Dynamic amplification.

5.1.5 The following important sources of cyclic loading should be considered in the design:

- Waves (including those which cause slamming and variable-buoyancy effects).
- Wind (especially when vortex shedding is induced, e.g., on slender members).
- Currents (where these influence the forces generated by waves and/or induced vortex shedding).
- Mechanical vibration (e.g., caused by operation of machinery).

5.1.6 Where a fine mesh finite element analysis is carried out to determine local geometric stress concentration factors, selection of associated S-N curves will be specially considered. Account is to be taken of fatigue stress direction relative to the weld. In general, the element mesh size adjacent to the weld detail under consideration is to be of the order of the local plate thickness. Mesh arrangement and analysis methodology are to be agreed with LR.

5.1.7 In general, stresses are to be determined using net scantlings, i.e., no corrosion allowance included, *see also* Pt 3, Ch 1,5.
For surface type units:
Where an approved corrosion control system is fitted, stresses can be determined using gross scantlings reduced by 25 per cent of corrosion addition.

5.2 Fatigue life assessment

5.2.1 Fatigue life assessment of all relevant structural elements is required to demonstrate that structural connections have a fatigue endurance consistent with the planned life of the unit and compliance with the minimum requirements. The following structural elements are to be included:

(a) Column-stabilised units:
- Bracing structure.
- Bracing connections to lower hulls, columns and decks.
- Column connections to lower hulls.
- Column connections to deck.
- Mooring structure and associated hull structure integration.
- General structural discontinuities.

(b) Surface type units:
- Hull longitudinal stiffener connections to transverse frames and bulkheads.
- Toe area of main structural brackets.
- Hopper knuckle connections.
- Main openings in the hull envelope.
- Mooring structure and associated hull structure integration.
- General structural discontinuities in the primary hull structure.

(c) Self-elevating units:
- Lattice legs and connections to footings.
- Leg support structure.
- Raw water towers.

(d) Other unit types:
- Special consideration will be given to the hull structure of other unit types on the basis of this Section.

(e) General: Hull, deck and supporting structure in way of topside facilities, e.g:
- Module support.
- Process plant support stools.
- Crane pedestal.
- Flare structures.
- Offloading station.
- Drilling derrick and substructures.

(f) General: Other structures subjected to significant cyclic loading.

5.2.2 Fatigue life is normally governed by the fatigue behaviour of welded joints, including both main and attachment welds. Structure is to be detailed and constructed to ensure that stress concentrations are kept to a minimum and that, where possible, components may deform without introducing secondary effects due to local restraints.

5.2.3 The minimum design fatigue life of a unit is to be specified by the Owner, but is not to be less than 25 years, unless agreed otherwise by LR.

5.3 Fatigue damage calculations

5.3.1 The fatigue damage calculations are to be based on the long-term distribution of the applied stress ranges. A sufficient number of draughts and directions are to be included.

5.3.2 An appropriate wave spectrum is to be used and representative percentages of the total cumulative spectrum included for each direction under consideration. When using a limited number of directions, account is to be taken of symmetry within the structure.

5.3.3 Cumulative damage may be calculated by Miner's summation:

$$\sum_{i=1}^{s} \left[\frac{n_i}{N_i}\right] \leq \frac{1,0}{F_s}$$

where

s = number of stress range blocks

n_i = actual number of cycles for stress range block number 'i'

N_i = corresponding number of cycles obtained from the relevant S-N curve for the detail under consideration

F_s = fatigue factor of safety from Table 5.5.1 or Table 5.5.2.

5.3.4 Cumulative damage for individual components is to take into account the degree of redundancy, accessibility of the structure and also the consequence of failure.

5.3.5 Fatigue life estimation is normally to be based on the Miner's summation method given in 5.3.3, but consideration will be given to the use of an appropriate fracture mechanics assessment.

5.4 Joint classifications and S-N curves

5.4.1 Acceptable joint classification and S-N curves for structural details are contained in Appendix A.

5.4.2 Consideration will be given to the use of alternative methods; detailed proposals are to be submitted and agreed with LR.

5.4.3 Full penetration welds are normally to be used for all nodal joints (i.e., tubular brace to chord connections). For full penetration welded joints, fatigue cracking would usually be located at the weld toe. However, if partial penetration welds have to be used where weld throat failure is a possibility, fatigue should be assessed using the 'W' curve and a shear stress estimated at the weld root.

5.4.4 For nodal joints, the stress range to be used in the fatigue analysis is the hot spot stress range at the weld toe. For any particular type of loading (e.g., axial loading) this stress range is the product of the nominal stress range in the brace and the appropriate stress concentration factor (SCF).

5.4.5 The hot spot stress is defined as the greatest value around the brace/chord intersection of the extrapolation to the weld toe of the geometric stress distribution near the weld toe. This hot spot stress incorporates the effects of overall joint geometry (i.e., the relative sizes of brace and chord) but omits the stress-concentrating influence of the weld itself which results in a local stress distribution. Hence, the hot spot stress is considerably lower than the peak stress but provides a consistent definition of stress range for the design S-N curve (curve 'T' shown in Appendix A). Stress ranges both for the brace and chord sides are to be considered in any fatigue assessment.

5.4.6 For all other types of joint (e.g., welded stiffeners or attachments, including those at nodal joints) the joint classifications and corresponding S-N curves are to take into account the local stress concentrations created by the joints themselves and by the weld profile. The relevant stress range is then the nominal stress range which is to include any local bending adjacent to the weld under consideration. However, if the joint is also situated in a region of stress concentration resulting from the gross shape of the structure, this is to be taken into account.

5.4.7 In load-carrying partial penetration or fillet-welded joints, where cracking could occur in the weld throat, the relevant stress range is the maximum range of shear stress in the weld metal. For details which are particularly fatigue-sensitive, where failure could occur through the weld, full penetration welding is normally to be used.

5.4.8 Geometric stress concentrations may be determined from experimental tests, appropriate references, semi-empirical or parametric formulae or analytical methods (e.g., finite elements analysis). *See also* Appendix A.

5.4.9 Normal fabrication tolerances according to good workmanship standards as given by the Rules are considered to be implicitly accounted for in the S-N curves.

5.5 Cast or forged steel

5.5.1 Fatigue life calculations for cast or forged steel structural components are to include details of the fatigue endurance curve for the material, taking account of the particular environment, mean stress and the existence of casting defects, and the derivation of any stress concentration factors.

5.6 Factors of safety on fatigue life

5.6.1 The minimum factors of safety on the calculated fatigue life of structural components are to be in accordance with Table 5.5.1. For mooring systems, *see* 5.6.2.

5.6.2 The minimum factors of safety on the calculated fatigue life of anchor lines and tether components of mooring systems are to be in accordance with Table 5.5.2.

Table 5.5.1 Fatigue life factors of safety for structural components

Inspectable/repairable	Fatigue life factor	
	Consequence of failure	
	Non-substantial	Substantial *See* Note 1
Yes, dry *See* Note 2	1	2
Yes, wet *See* Note 3	2	4
No	3	10

NOTES
1. Substantial consequences of failure include, *inter alia*, loss of life, uncontrolled outflow of hazardous or polluting products, collision, sinking. In assessing consequences, account should be taken of the potential for progressive failure. This factor will be applicable for bottom structure of oil storage tanks of single bottomed units and side structures of oil storage tanks of single sided units.
2. Includes internal and external structural elements and connections which can be subjected to dry inspection and repair.
3. Includes external structural elements and connections situated below the minimum operating draught of the unit or structure which can only be inspected during in-water surveys but dry repairs could be carried out subject to special arrangements being provided.

Table 5.5.2 Fatigue life factors of safety for anchor line and tether components

Inspectable/replaceable	Fatigue life factor
Yes, dry	3
Yes, wet	5
No	10

NOTE
Anchor line or tether components include chains, steel wire ropes, and associated fittings such as shackles, connecting links, rope sockets and terminations.

Section

■ *Section 1* General requirements

1.1 General

1.1.1 All parts of the structure are to be designed to withstand the most severe combination of overall and local loadings to which they may be subjected. Permissible stresses for direct calculation methods are to comply with the requirements of Chapter 5.

1.1.2 The local effects of the loadings listed in Ch 3,4 are to be considered and all parts of the structure are to be examined individually as necessary, and the calculations submitted. The minimum Rule scantlings of all structures are also to comply with the requirements of this Chapter, as applicable.

1.1.3 The design heads for local strength of column-stabilised, sea-bed stabilised and self-elevating units are to be in accordance with Section 2.

1.1.4 The design heads for local strength of surface type units are to be in accordance with Pt 3, Ch 3,5 of the Rules for Ships.

1.1.5 The scantlings of machinery seatings are to be specially considered. On self-propelled units, full details of power, and RPM, etc., are to be submitted.

1.1.6 The structure in way of fairleads, chainstoppers, winches, etc., forming part of anchoring or positional mooring systems is to be designed for a working load equal to the breaking strength of the mooring or anchoring lines as applicable, *see also* Pt 3, Ch 10,11. Permissible stresses are to be in accordance with Ch 5,2.1.1(c). Supply boat moorings and support structures are to be designed on a similar basis.

1.1.7 Towing brackets and supporting structure are to be designed for a working load equal to the breaking strength of the towline in accordance with the requirements of Chapter 9.

1.1.8 The supporting structure in way of lifeboat davits is to be designed for the dynamic factors defined in Ch 4,1.9 and the permissible stress levels are to comply with loadcase (a) in Ch 5,2.1.1.

1.1.9 When a **DRILL** notation is to be assigned, the scantlings of the drilling derrick are to be determined in accordance with Pt 3, Ch 7. The supporting sub-structure is a classification item and calculations are to be submitted in accordance with Pt 3, Ch 7. The sub-structure is to be integrated into the unit's hull structure and the local permissible stresses are to comply with Chapter 5.

1.1.10 The supporting structures to production and process plant are to comply with Pt 3, Ch 8.

■ *Section 2* Design heads

2.1 General

2.1.1 This Section contains the local design heads and pressures to be used in the derivation of scantlings for decks, and bulkheads. Where scantlings in excess of Rule requirements are fitted the procedure to be adopted to determine the permissible head/pressure is also given.

2.2 Symbols

2.2.1 The symbols used in this Section are defined as follows:

L and D as defined in Ch 1,5

h_i = appropriate design head, in metres

p = design loading, in kN/m^2 (tonne-f/m^2)

p_a = applied loading, in kN/m^2 (tonne-f/m^2)

C = stowage rate, in m^3/tonne, *see* 2.3

$= \dfrac{h_i}{p}$

E = correction factor for height of platform

$= \dfrac{0{,}0914 + 0{,}003L}{D - T} - 0{,}15$, but not less than zero nor more than 0,147

T = T_0 or T_T as defined in Ch 1,5 as appropriate.

2.3 Stowage rate and design heads

2.3.1 The following standard stowage rates are to be used:

(a) 1,39 m^3/tonne for weather or general loading on decks.

(b) 0,975 m^3/tonne for tanks with liquid of density 1,025 tonne/m^3 or less on tank bulkheads and for watertight bulkheads. For liquid of density greater than 1,025 tonne/m^3, the corresponding stowage rates are to be adopted.

2.3.2 The design heads and permissible deck loading are shown in Table 6.2.1. For helicopter landing areas, *see* Section 5.

Table 6.2.1 Design heads and permissible deck loadings (SI units) (*see continuation*)

Structural item and position	Component	Standard stowage rate C, in m^3/tonne	Design loading p, in kN/m^2	Equivalent design head h_i in metres	Permissible deck loading in kN/m^2	Equivalent permissible head, in metres
1. All units except surface type units						
(a) Weather decks	—	—	—	h_1	—	—
(b) Loading for minimum scantlings						
(i) Exposed deck	All structure	1,39	$9,0 + 14,41E$	$1,2 + 2,04E$	9,0	1,2
(c) Specified deck loading						
(i) Exposed deck	All structure	1,39	$p_a + 14,41E$ but not less than (a) above	$0,14p_a + 2,04E$	p_a	$0,14p_a$
2. Other decks						
(a) Loading for minimum scantlings						
(i) Work areas	All structure	1,39	9,0	h_2 1,28	—	—
(ii) Storage areas	All structure	1,39	14,13	h_3 2,0	—	—
(iii) Decks forming crown of deep tanks	All structure	C	$\frac{9,82h}{c}$ (*see* Note 2)	h_4 h (*see* Note 2)	—	—
(iv) Accommodation decks	All structure	1,39	8,5	h_5 1,2	—	—
(b) Specified deck loading						
(i) All areas	All structure	1,39	$p_a + 14,41E$ but not less than (a) above	h_2, h_3, h_5 $0,14p_a$	—	—
(c) Superstructure decks (*see* Note 3)				h_6		
(i) 1st tier (ii) 2nd tier (iii) 3rd tier and above	All structure	—	—	0,9 0,6 0,45 (*see* Note 4)	—	—
(d) Walkways and access areas	All structure	1,39	4,5	h_7 0,64	—	—

Table 6.2.1 Design heads and permissible deck loadings (SI units) (*conclusion*)

Structural item and position	Component	Standard stowage rate C, in m^3/tonne	Design loading p, in kN-f/m^2	Equivalent design head h_i in metres	Permissible deck loading in kN-f/m^2	Equivalent permissible head, in metres
3. Watertight bulkheads	All structure	0,975	$10{,}07h_4$	h_4 *see* Table	—	—
4. Deep tank bulkheads	All structure	C but ≤ 0,975	$\dfrac{9{,}82h_4}{C}$	h_4 *see* Table 6.7.1	—	—

NOTES
1. The equivalent design head is to be used in conjunction with the appropriate formulae in the Rules.
2. Where h equals half the distance to the top of the overflow above crown of tank.
3. For forecastle decks forward of $0{,}12L$ from F.P., *see* weather decks.
4. Where the deck is exposed to the weather add $2{,}04E$ to the design head.

Table 6.2.1 Design heads and permissible deck loadings (metric units) (*see continuation*)

Structural item and position	Component	Standard stowage rate C, in m^3/tonne	Design loading p, in tonne-f/m^2	Equivalent design head h_i in metres	Permissible deck loading in tonne-f/m^2	Equivalent permissible head, in metres
1. All units except surface type units						
(a) Weather decks	—	—	—	h_1	—	—
(b) Loading for minimum scantlings						
(i) Exposed deck	All structure	1,39	0,92 + 1,467E	1,28 + 2,04E	0,92	1,28
(c) Specified deck loading						
(i) Exposed deck	All structure	1,39	p_a + 1,467E but not less than (a) above	1,39p_a + 2,04E	p_a	1,39p_a
2. Other decks						
(a) Loading for minimum scantlings						
(i) Work areas	All structure	1,39	0,92	h_2 1,28	—	—
(ii) Storage areas	All structure	1,39	1,44	h_3 2,0	—	—
(iii) Decks forming crown of deep tanks	All structure	C	$\frac{h}{C}$ (*see* Note 2)	h_4 h (*see* Note 2)	—	—
(iv) Accommodation decks	All structure	1,39	0,865	h_5 1,2	—	—
(b) Specified deck loading						
(i) All areas	All structure	1,39	p_a but not less than (a) above	h_2, h_3, h_5 1,39p_a	—	—
(c) Superstructure decks (*see* Note 3)				h_6		
(i) 1st tier (ii) 2nd tier (iii) 3rd tier and above	All structure	—	—	0,9 0,6 0,45 (*see* Note 4)	—	—
(d) Walkways and access areas	All structure	1,39	0,46	h_7 0,64	—	—

Table 6.2.1 Design heads and permissible deck loadings (metric units) *(conclusion)*

Structural item and position	Component	Standard stowage rate C, in m^3/tonne	Design loading p, in tonne-f/m^2	Equivalent design head h_i in metres	Permissible deck loading in tonne-f/m^2	Equivalent permissible head, in metres
3. Watertight bulkheads	All structure	0,975	$\dfrac{h_4}{0,975}$	h_4 see Table 6.7.1	—	—
4. Deep tank bulkheads	All structure	C but $\leq$ 0,975	$\dfrac{h_4}{C}$	h_4 see Table 6.7.1	—	—

NOTES
1. The equivalent design head is to be used in conjunction with the appropriate formulae in the Rules.
2. Where h equals half the distance to the top of the overflow above crown of tank.
3. For forecastle decks forward of 0,12L from F.P., *see* weather decks.
4. Where the deck is exposed to the weather add 2,04E to the design head.

Section 3
Watertight shell boundaries

3.1 General

3.1.1 The requirements of Chapter 7 regarding watertight integrity are to be complied with.

3.1.2 The minimum requirements for watertight shell plating and framing of column-stabilised units and self-elevating units are given in this Section.

3.1.3 The minimum requirements for watertight shell plating and framing of surface type units are to comply with Ch 4,4.

3.1.4 The Rules are, in general, applicable to shell plating with stiffeners fitted parallel to the hull bending compressive stress. When other stiffening arrangements are proposed, the scantlings are to be specially considered and the minimum shell thickness is to satisfy the buckling strength requirements given in Chapter 5, but the minimum requirements of this Section are to be complied with.

3.1.5 The shell plating thickness is to satisfy the requirements for the overall strength of the unit in accordance with Chapters 4 and 5.

3.1.6 The scantlings of moonpool bulkheads will be specially considered with regard to the maximum forces imposed on the structure and the permissible stress levels are to comply with Chapter 5.

3.1.7 The minimum scantlings of moonpools and drilling well bulkheads on column-stabilised units are to comply with 3.2.5, but plating thickness is to be not less than 9,0 mm, *see also* Pt 3, Ch 2,2.

3.1.8 The scantlings of moonpools and drilling well bulkheads on surface type units and self-elevating units are to comply with Pt 3, Ch 2,2.

3.1.9 Where column structures or superstructures extend over the side shell of the unit, the side shell/sheerstrake is to be suitably increased locally at the ends of the structure.

3.1.10 On units fitted with two chines each side the bilge plating should not be less than required for bottom plating. When units are fitted with hard chines the shell plating is not to be flanged, but where the chine is formed by knuckling the shell plating, the radius of curvature, measured on the inside of the plate, is not to be less than 10 times the plate thickness. Where a solid round chine bar is fitted, the bar diameter is to be not less than three times the thickness of the thickest abutting plate. Where welded chines are used, the welding is to be built up as necessary to ensure that the shell plating thickness is maintained across the weld, *see also* Table 6.3.3.

3.1.11 The plating of swim ends is to have a thickness not less than that required for bottom shell plating.

3.1.12 Where a rounded sheerstrake is adopted, the radius should, in general, be not less than 15 times the plate thickness.

3.1.13 Sea inlets, or other openings, are to have well rounded corners and, so far as possible, are to be kept clear of the bilge radius. Openings on, or near to, the bilge radius are to be elliptical. The thickness of sea inlet box plating is to be the same as the adjacent shell, but not less than 12,5 mm. The ends of stiffeners should in general be bracketed and alternative proposals may be considered.

3.1.14 In general, secondary hull framing is to be continuous and the end connections of stiffeners to watertight bulkheads are to provide adequate fixity and, so far as practicable, direct continuity of strength.

3.1.15 The end connections of secondary hull framing and primary members are also to comply with Chapter 8.

3.1.16 The lateral and torsional stability of stiffeners together with web and flange buckling criteria are to be verified in accordance with Ch 5,3.

3.1.17 Web frames supporting secondary hull framing are, in general, to be spaced not more than 3,8 m apart when the length, L, is less than 100 m and (0,006L + 3,2) m apart where L is greater than 100 m. For units which are also required to operate aground, *see* Ch 4,2.

3.2 Column-stabilised units

3.2.1 When the external watertight boundaries of columns, lower hulls and footings are designed with stiffened plating, the minimum scantlings for shell plating, hull framing and web frames, etc., are to comply with Table 6.3.1, *see also* 3.2.3.

3.2.2 The scantlings determined from Table 6.3.1 are the minimum requirements for hydrostatic pressure loads only and the overall strength is to comply with Chapter 4.

3.2.3 Where cross ties are fitted in columns or lower hulls, the scantlings are to comply with 3.3.5 and 3.3.6 taking the head h_c as the pressure head h_o in accordance with Table 6.3.1 as appropriate. Where cross ties are fitted inside tanks, the requirements of 3.3.4 are also to be complied with.

Table 6.3.1 Watertight shell boundaries for lower hulls and columns of column-stabilised units and tension-leg units

Items and requirement	Boundaries of lower hull or columns
(1) Shell plating thickness *See also* 3.1.5	$t = 0{,}004 s f \sqrt{h_o k} + 2{,}5$ mm but not less than 9,0 mm
(2) Hull framing: (a) Modulus (b) Inertia	$Z = 8{,}5 s\, k\, h_o\, l_e^2 \times 10^{-3}$ cm^3 $I = \dfrac{2{,}3}{k}\, l_e Z$ cm^4
(3) Primary members: Web frames supporting framing: (a) Modulus (b) Inertia	$Z = 8{,}5 k\, h_o\, S\, l_e^2$ cm^3 $I = \dfrac{2{,}3}{k}\, l_e Z$ cm^4

Symbols

f = $1{,}1 - \dfrac{s}{2500S}$ but not to be taken greater than 1,0

h_o = load head in metres measured vertically as follows:
- (a) For shell plating the distance from a point one-third of the height of the plate above its lower edge to a point 1,4T_0 above the keel or to the bottom of the upper hull structure whichever is the lesser with a minimum of 6,0 m.
- (b) For hull framing and primary members, the distance from the middle of the effective length to a point 1,4T_0 above the keel or to the bottom of the upper hull structure whichever is the lesser with a minimum of 6,0 m.

k = steel factor as defined in Ch 2,1
l_e = effective length of member, in metres, as defined in Ch 3,3.3
s = spacing of frames, in mm
S = spacing or mean spacing of primary members, in metres
T_0 = maximum operating draught, in metres, as defined in Ch 1,5

NOTES
1. In no case are the scantlings in way of tanks to be less than the requirements given in Table 6.7.1 for tank bulkheads using the load head h_4.
2. In no case are the scantlings to be less than the requirements given in Table 6.7.1 for watertight bulkheads using the load head h_4.
3. Where frames are not continuous they are to be fitted with end brackets in accordance with Section 7 or equivalent arrangements provided.

3.2.4 When the scantlings of primary web frames or girders are determined by a frame analysis or where the boundaries of columns, lower hulls and footings are designed as shells either unstiffened or ring stiffened, the scantlings may be determined on the basis of an agreed analysis, *see* Ch 1,2. The minimum design loads are to be in accordance with Chapter 3 and the permissible stresses are to comply with Chapter 5. The scantlings are not to be less than required by 3.2.1.

3.2.5 The minimum scantlings of the external watertight boundaries of the upper hull structure are to comply with Table 6.3.2.

3.2.6 The shell plating and structure are to be reinforced in way of mooring fairleads, supply boat moorings, towing brackets and other attachments, *see also* Section 1.

3.2.7 Columns, lower hulls, footings and other areas likely to be damaged by anchors, chain cables and wire ropes, etc., are to be protected or suitably strengthened.

3.2.8 Openings are not permitted in the shell boundaries of columns, lower hulls and footings except when they are closed with watertight covers fitted with closely spaced bolts, *see* Chapter 7.

3.3 Self-elevating units

3.3.1 The minimum scantlings of shell plating are to comply with Table 6.3.3 and the secondary hull framing and primary members are to comply with Table 6.3.4, *see also* 3.3.4.

3.3.2 The shell plating thickness is to be suitably increased in way of high shear forces in way of drilling cantilevers and other concentrated loads.

3.3.3 The scantlings and arrangements of the boundary bulkheads of leg wells will be specially considered with regard to the maximum forces imposed on the structure, and the permissible stress levels are to comply with Chapter 5. The minimum scantlings are to comply with Table 6.7.1 as a tank bulkhead with the load head h_4 measured to the upper deck at side. In no case is the minimum plating thickness to be less than 9 mm.

3.3.4 When cross ties are fitted inside pre-load tanks, the tensile stress in the cross ties and its end connections is not to exceed 108 N/mm^2 (11,0 kgf/mm^2) at the test head, but the scantlings are also to comply with the requirements of 3.3.5 and 3.3.6.

Table 6.3.2 Watertight shell boundaries of the upper hull of column-stabilised units and tension-leg units

Items and requirement	Boundaries of upper hull
(1) Shell plating thickness general *See also* 3.1.5	The greater of the following: (a) $t = 0{,}004sf\sqrt{h_4 k}$ mm (b) $t = 0{,}012s_1\sqrt{k}$ but not less than 7,5 mm
(2) Bottom plating thickness between columns within $\frac{W}{2}$ outside of column shell but not less than two web frame spaces *See also* 3.1.5	The greater of the following: (a) $t = 0{,}004s\,f\sqrt{h_4 k} + 2{,}5$ mm (b) $t = 0{,}012s_1\sqrt{k}$ but not less than 7,5 mm
(3) Shell stiffeners and primary webs, general	To comply with Table 6.7.1 using the load head h_4
(4) Shell stiffeners adjacent to columns as defined in (2): (a) Modulus (b) Inertia	$Z = 8{,}5s\,k\,h_4\,l_e^2 \times 10^{-3}$ cm^3 $I = \frac{2{,}3}{k}\,l_e\,Z$ cm^4

Symbols

Symbols as defined in Table 6.7.1, except as follows:

h_4 = load head, in metres, as defined in Table 6.7.1 for watertight bulkheads but not less than 6,0 m

$s_b = 470 + \frac{L}{0{,}6}$ mm or 700, whichever is the smaller

s_1 = s but is not to be taken less than s_b

W = greatest width or diameter of stability column, in metres

NOTE

In no case are the scantlings in way of tanks to be less than the requirements given in Table 6.7.1 for tank bulkheads using the load head h_4.

Table 6.3.3 Shell plating self-elevating units

Location	Thickness, in mm, *see also* 3.1.5
(1) Bottom shell plating *See* Notes 1, 2 and 4	The greater of the following: (a) $t = 0{,}001s_1\,(0{,}043L + 10)\sqrt{\dfrac{1}{k}}$ (b) $t = 0{,}0052s_1\sqrt{1{,}5T_T\,k}$
(2) Bilge plating (framed) *See* Note 2	t as for (1)
(3) Side shell plating *See* Notes 1, 2, 3 and 4	(a) Above $\dfrac{D}{2}$ from base: The greater of the following: (i) $t = 0{,}001s_1\,(0{,}059L + 7)\sqrt{\dfrac{1}{k}}$ (ii) $t = 0{,}0042s_1\sqrt{1{,}4T_T\,k}$ (b) At upper turn of bilge (*see* Note 2): The greater of the following: (i) $t = 0{,}001s_1\,(0{,}059L + 7)\sqrt{\dfrac{1}{k}}$ (ii) $t = 0{,}0054s_1\sqrt{1{,}2T_T\,k}$ (c) Between upper turn of bilge and $\dfrac{D}{2}$ from base: The greater of the following: (i) t from (b)(i) (ii) t from interpolation between (a)(ii) and (b)(ii)
(4) Minimum plating	$t_m = (6{,}5 + 0{,}033L)\sqrt{\dfrac{ks_1}{s_b}}$

Symbols

L, D, T_T, as defined in Ch 1,5

k = steel factor as defined in Ch 2,1

s = spacing of secondary stiffeners, in mm

$s_b = 470 + \dfrac{L}{0{,}6}$ mm or 700 mm, whichever is the smaller

$s_1 = s$, but is not to be taken less than s_b

NOTES

1. In no case is the shell plating to be less than t_m.
2. When no bilge radius is fitted and the unit is fitted with hard chines, the bottom shell thickness required by (1) is, in general, to be extended up to $\dfrac{D}{4}$ from base, *see* 3.1.10.
3. The thickness of side shell need not exceed that determined from (1) for bottom shell when using the spacing of side shell stiffeners.
4. In no case are the scantlings of tanks to be less than the requirements given in Table 6.7.1 for tank bulkheads using load head h_4.

3.3.5 When cross ties are fitted to support shell web frames the scantlings of the web frames are to be determined from Tables 6.3.4 and 6.7.1 and the area and least moment of inertia of the cross tie are to satisfy the following, *see also* 3.3.6 and 3.3.7:

$$A_c \geq \frac{0{,}82b_c\,h_c\,S\,k}{1 - 0{,}42\left(\dfrac{l_c}{r\sqrt{k}}\right)}$$

where:

b_c = one-half the vertical distance in metres between the centres of the bottom or deck webs adjacent to the cross tie, *see* Fig. 6.3.1

h_c = vertical distance from the centre of the cross tie to deck, in metres, *see* Fig. 6.3.1

l_c = length of cross tie between the toes of the horizontal brackets on the web frames at the cross tie, in metres

S = spacing of web frames, in metres

l_e = span of web frames, *see* Fig. 6.3.1

I_c = least inertia of cross tie cross-section, in cm^4

A_c = area of cross tie, in cm^2

r = least radius of gyration of cross tie cross-section, in cm

Table 6.3.4 Shell framing self-elevating units

Items and location	Modulus
(1) Hull framing, *see* Note 1	
(a) Bottom frames	$Z = 11{,}0s\,k\,h_T\,l_e^2 \times 10^{-3}$ cm^3
(b) Side frames	$Z = 8{,}0s\,k\,h_T\,l_e^2 \times 10^{-3}$ cm^3
(2) Primary members, *see* Note 1	
(a) Bottom web frames supporting framing	$Z = 11{,}0k\,h_T\,S\,l_e^2 \times 10^{-3}$ cm^3
(b) Side web frames supporting framing	$Z = 8{,}0k\,h_T\,S\,l_e^2 \times 10^{-3}$ cm^3

Symbols

D and T_T as defined in Ch 1,5

h_T = load head, in metres, and is to be taken as the distance from the middle of the effective length to a point $1{,}6T_T$ above the keel or to the upper deck at side whichever is the lesser but not less than $0{,}01L + 0{,}7$

k = steel factor as defined in Ch 2,1

l_e = effective length of member, in metres, as defined in Ch 3,3.3

s = spacing of frames, in mm

S = spacing or mean spacing of primary members, in metres

NOTES

1. In no case are the scantlings in way of tanks to be less than the requirements given in Table 6.7.1 for tank bulkheads using the load head h_4.
2. In no case are the scantlings to be less than the requirements given in Table 6.7.1 for watertight bulkheads using the load head h_4.
3. Where frames are not continuous they are to be fitted with end brackets in accordance with Section 7 or equivalent arrangements provided.

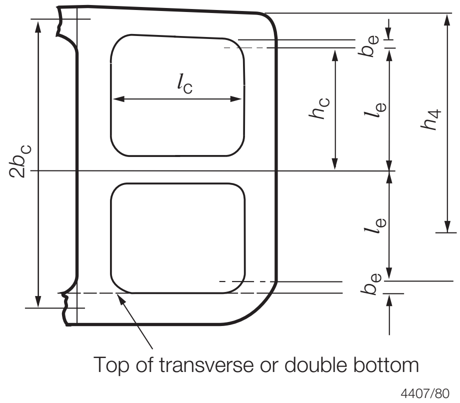


Fig. 6.3.1 Cross tie construction

$$= \sqrt{\frac{I_c}{A_c}}$$

b_e as defined in Ch 3,3.3.

3.3.6 The scantlings of the webs and flanges of cross ties are to be checked for buckling by direct calculation.

3.3.7 Design of end connections of cross ties is to be such that the area of the welding, including vertical brackets, where fitted, is to be not less than the minimum cross sectional area of the cross tie derived from 3.3.5. To achieve this, full penetration welds may be required and thickness of brackets may require further consideration. Attention is to be given to the full continuity of area of the backing structure on the transverses. Particular attention is also to be paid to the welding at the toes of all end brackets on the cross tie.

Section 4 **Decks**

4.1 General

4.1.1 The design deck loadings for all unit types are not to be less than those defined in Sections 1 and 2.

4.1.2 The scantlings of deck structures for surface type units are to comply with Ch 4,4. The requirements of 4.1.5 and 4.1.6 are also to be complied with as applicable.

4.1.3 The minimum scantlings of deck structures on column-stabilised units and self-elevating units are to comply with this Section.

4.1.4 The scantlings of deck structures are also to satisfy the overall strength requirements in Chapter 4 and be sufficient to withstand the actual local loadings plus any additional loadings superimposed due to overall frame action. The permissible stress levels are to comply with Chapter 5.

4.1.5 Where decks form watertight boundaries in damage stability conditions, the minimum scantlings are not to be less than required for watertight bulkheads given in Section 7.

4.1.6 For units fitted with a process plant facility and/or drilling equipment, the support stools and integrated hull support structure to the process plant and other equipment supporting structures to drilling derricks and flare structures, etc., are considered to be classification items regardless of whether or not the process/drilling plant facility is classed and the loadings are to be determined in accordance with Pt 3, Ch 8,2. Permissible stress levels are to comply with Chapter 5.

4.2 Deck plating

4.2.1 The requirements are in general applicable to strength/weather deck plating with stiffeners fitted parallel to the hull bending compressive stress. When other stiffening arrangements are proposed, the scantlings will be specially considered, but the minimum requirements of Table 6.4.1 are to be complied with.

4.2.2 The minimum thickness of deck plating is to comply with the requirements of Table 6.4.1, except for decks in way of erections above the upper deck. For erection decks, *see* Section 6.

4.2.3 The thickness of strength/weather deck plating is also to be that necessary to satisfy the overall strength requirements of Chapters 4 and 5.

4.2.4 The deck plating thickness and supporting structure in way of towing brackets, winches, masts, crane pedestals, davits and machinery items, etc., is to be suitably reinforced, *see also* Section 1.

4.2.5 Where plated decks are sheathed with wood or approved compositions, consideration will be given to allowing a reduction in the minimum plating thickness given in Table 6.4.1.

4.3 Deck stiffening

4.3.1 The scantlings of deck stiffeners are to comply with the requirements of Table 6.4.2. Stiffeners fitted in way of concentrated loads and heavy machinery items, etc., will be specially considered.

4.3.2 The lateral and torsional stability of stiffeners together with web and flange buckling criteria are to be verified in accordance with Ch 5,3.

4.3.3 End connection of stiffeners to bulkheads are to provide adequate fixity and, so far as practicable, direct continuity of primary strength. In general deck stiffeners are to be continuous through primary support structure, including bulkheads but alternative arrangements will be considered. The end connections of stiffeners are in general to be in accordance with the requirements of Chapter 8.

Table 6.4.1 Deck plating

Symbols	Location	Thickness, in mm, *see also* 4.2.2
b = breadth of increased plating, in mm f = $1{,}1 - \dfrac{s}{2500S}$ but not to be taken greater than 1,0 k = steel factor as defined in 2.1.2 s = spacing of deck stiffeners, in mm s_1 = s but is to be taken not less than the smaller of: $470 + \dfrac{L}{0{,}6}$ mm or 700 mm A_f = girder face area, in cm^2 K_1 = 2,5 mm at bottom of tank = 3,5 mm at the crown of tank L = length of unit, in metres, as defined in Ch 1,5.1 S = spacing of primary members, in metres ρ, h_4 as defined in Table 6.7.1	(1) Strength/weather deck *See* Notes 1 and 2	The greater of the following: (a) $t = 0{,}001s_1\,(0{,}059L + 7)\sqrt{\dfrac{1}{k}}$ (b) $t = 0{,}00083s_1\sqrt{Lk} + 2{,}5$ but not less than (2)
	(2) Lower decks	$t = 0{,}012s_1\sqrt{k}$ but not less than 7,0 mm
	(3) Platform decks	$t = 0{,}01s_1\sqrt{k}$ but not less than 6,5 mm
	(4) In way of the crown or bottom of tanks	$t = 0{,}004sf\sqrt{\dfrac{\rho\,k\,h_4}{1{,}025}} + K_1$ or as (1), (2) or (3) whichever is the greater but not less than 7,5 mm
	(5) Plating forming the upper flange of underdeck girders	$t = \sqrt{\dfrac{A_f}{1{,}8k}}$ but not less than required by (1), (2), (3) or (4) as appropriate Minimum breadth, b = 760 mm

NOTES
1. The thickness derived in accordance with (1) is also to satisfy the buckling requirements of Chapter 5.
2. On column-stabilised units when the primary deck structure consists of box girders or equivalent structure and the deck plating is considered as secondary structure only the thickness of the plating will be specially considered but in no case is the thickness to be less than 6,5 mm.
3. Where the local deck loading exceeds 43,2 kN/m^2 (4,4 tonne-f/m^2) the thickness of plating will be specially considered.

Table 6.4.2 Deck stiffeners

Symbols	Location	Modulus, in cm^3	Inertia, in cm^4
d_w = depth of stiffener, in mm, *see* Note 2 h_1 = weather head, in metres h_2 = work area head, in metres h_3 = storage head, in metres h_4 = tank head, in metres, as defined in Table 6.7.1 h_5 = accommodation head, in metres k = steel factor defined in Ch 2,1.2 l_e = span point, in metres as defined in Ch 3,3.3 but not less than 1,5 m s = spacing of stiffeners, in mm γ = 1,4 for rolled or built sections = 1,6 for flat bars ρ as defined in Table 6.7.1	(1) Weather decks	$Z = 5{,}5 s\, k\, h_1\, l_e^2 \times 10^{-3}$	—
	(2) Work areas	$Z = 5{,}5 s\, k\, h_2\, l_e^2 \times 10^{-3}$	—
	(3) Storage areas	$Z = 5{,}0 s\, k\, h_3\, l_e^2 \times 10^{-3}$	—
	(4) Accommodation decks and crew spaces	$Z = 4{,}5 s\, k\, h_5\, l_e^2 \times 10^{-3}$	—
	(5) In way of the crown or bottom of tanks	As (1), (2), (3) or (4) as applicable, or $\dfrac{0{,}0113 \rho\, s\, k\, h_4\, l_e^2}{\gamma}$ whichever is the greater	$I = \dfrac{2{,}3}{k}\, l_e\, Z$

NOTES
1. The load heads h_1, h_2, h_3 and h_5 are to be determined from the maximum design uniform loadings and are not to be less than the minimum design load heads given in Table 6.2.1.
2. The web depth, d_w, of stiffeners is to be not less than 60 mm.

4.4 Deck supporting structure

4.4.1 The minimum scantlings of girders and transverses supporting deck stiffeners are to comply with the requirements of Table 6.4.3.

4.4.2 Transverses supporting deck longitudinals are, in general, to be spaced not more than 3,8 m apart when the length, L, is 100 m or less, and $(0{,}006L + 3{,}2)$ m apart where L is greater than 100 m.

4.4.4 Where a girder is subject to concentrated loads, such as pillars out of line, the scantlings are to be suitably increased. Also, where concentrations of loading on one side of the girder may occur, the girder is to be adequately stiffened against torsion.

4.4.5 Pillars are to comply with the requirements of Table 6.4.4.

4.4.6 Pillars are to be fitted in the same vertical line wherever possible, and effective arrangements are to be made to distribute the load at the heads and heels of all pillars. Where pillars support eccentric loads, they are to be strengthened for the additional bending moment imposed upon them.

4.4.7 Tubular and hollow square pillars are to be attached at their heads to plates supported by efficient brackets, in order to transmit the load effectively. Doubling or insert plates are to be fitted to decks under the heels of tubular or hollow square pillars. The pillars are to have a bearing fit and are to be attached to the head and heel plates by continuous welding. At the heads and heels of pillars built of rolled sections, the load is to be well distributed by means of longitudinal and transverse brackets.

4.4.8 Where pillars are not fitted directly above the intersection of bulkheads, equivalent arrangements are to be provided.

4.4.9 In double bottoms where pillars are not directly above the intersection of the plate floors and girders, partial floors and intercostals are to be fitted as necessary to support the pillars. Manholes are not to be cut in floors and girders below the heels of pillars.

4.4.10 Where pillars are fitted inside tanks or under watertight flats, the tensile stress in the pillar and its end connections is not to exceed 108 N/mm^2 (11,0 kgf/mm^2) at the test heads. In general, such pillars should be of built sections, and end brackets may be required.

4.4.11 Pillars or equivalent structures are to be fitted below deckhouses, machinery items, winches, etc., and elsewhere where considered necessary.

4.4.12 The thickness of primary longitudinal and transverse bulkheads supporting decks is to satisfy the requirements for the overall strength of the unit in accordance with Chapters 4 and 5. When the bulkheads are to be watertight the scantlings are also to comply with the requirements of Section 7.

4.4.13 The lateral and torsional stability of primary bulkhead stiffeners together with web and flange buckling criteria are to be verified in accordance with Ch 5,3.

4.4.14 When openings are cut in the primary longitudinal and transverse bulkheads the openings are to have well rounded corners and full compensation is to be provided. All openings are to be adequately framed.

4.4.15 The minimum scantlings of non-watertight pillar bulkheads are to comply with the requirements of Table 6.4.5.

Table 6.4.3 Deck girders, transverses and deep beams

Location and arrangements	Modulus, in cm^3	Inertia, in cm^4
(1) Girders and transverses in way of dry spaces: (a) Supporting point loads (b) Supporting a uniformly distributed load	Z to be determined from calculations using stress $\frac{123,5}{k}$ N/mm^2 $\left(\frac{12,6}{k}\right.$ kgf/mm$^2\left.\right)$ and assuming fixed ends $Z = 4,75k\,S\,H_g\,l_e^2$	$I = \frac{1,85}{k}\,l_e\,Z$
(2) Deep beams supporting deck girders in way of dry spaces: (a) Supporting point loads (b) Supporting a uniformly distributed load	Z to be determined from calculations using stress $\frac{123,5}{k}$ N/mm^2 $\left(\frac{12,6}{k}\right.$ kgf/mm$^2\left.\right)$ and assuming fixed ends $Z = 4,75k\,S\,H_g\,l_e^2$	$I = \frac{2,3}{k}\,l_e\,Z$
(3) Girders and transverses in way of the crown or bottom of tanks	$Z = 11,7\rho\,k\,h_4\,S\,l_e^2$	$I = \frac{2,5}{k}\,l_e\,Z$

Symbols

h_4 = tank head, in metres, as defined in Table 6.7.1
k = steel factor as defined in Ch 2,1.2
l_e = span point, in metres, defined in Ch 3,3.3
H_g = weather head h_1 or work area head h_2 or storage head h_3 or accommodation head h_5, in metres, as defined in Table 6.2.1 whichever is applicable
S = spacing of primary members, in metres
ρ as defined in Table 6.7.1

4.5 Deck openings

4.5.1 The corners of all deck openings are to be elliptical, parabolic or well rounded and the free edges are to be smooth. Large openings are to comply with 4.5.4 and 4.5.5.

4.5.2 All openings are to be adequately framed. Attention is to be paid to structural continuity, and abrupt changes of shape, section or plate thickness are to be avoided.

4.5.3 Arrangements in way of corners and openings are to be such as to minimise the creation of stress concentrations. Openings in highly stressed areas of decks, having a stress concentration factor in excess of 2,4, will require edge reinforcements in the form of a spigot of adequate dimensions, but alternative arrangements will be considered. The area of any edge reinforcement which may be required is not to be taken into account in determining the required sectional area of compensation for the opening.

4.5.4 When large openings are cut in highly stressed areas of decks, the corners of the openings are to be elliptical, parabolic or rounded, with a radius generally not less than 1/24 of the breadth of the opening. The minimum radius for large openings is to be 150 mm, provided the inner edge of the plating is stiffened by means of a coaming or spigot. Where the inner edge is unstiffened, the minimum radius is to be 300 mm.

4.5.5 Where the corners of large openings are rounded, the deck plating thickness is to be increased at the corners of the openings.

4.5.6 Compensation will be required for deck openings cut in highly stressed areas.

4.5.7 All openings which are required to be made watertight or weathertight are to have closing appliances in accordance with the requirements of Chapter 7.

Table 6.4.4 Pillars

Symbols	Parameter	Requirement
b = breadth of side of a hollow rectangular pillar or breadth of flange or web of a built or rolled section, in mm d_p = mean diameter of tubular pillars, in mm k = local scantling higher tensile steel factor, *see* Ch 2,1.2.1, but not less than 0,72 l = overall length of pillar, in metres l_e = effective length of pillar, in metres, and is taken as $0{,}80l$ r = least radius of gyration of pillar cross-section, in mm, and may be taken as: $r = 10\sqrt{\dfrac{I}{A_p}}$ mm A_p = cross-sectional area of pillar, in cm^2 H_g as defined in Table 7.4.3 I = least moment of inertia of cross-section, in cm^4 P = load, in kN (tonne-f), supported by the pillar and is to be taken as: $P = P_o + P_a$ but not less than 19,62 kN (2 tonne-f) P_a = load, in kN (tonne-f), from pillar or pillars above (zero if no pillars over) P_o = load, in kN (tonne-f), supported by pillar based on H_g	(1) Cross-sectional area of all types of pillar	$A_p = \dfrac{k\,P}{12{,}36 - 51{,}5\dfrac{l_e}{r\sqrt{k}}}$ cm^2 $\left(A_p = \dfrac{k\,P}{1{,}26 - 5{,}25\dfrac{l_e}{r\sqrt{k}}}\ cm^2\right)$ *See* Note
	(2) Minimum wall thickness of tubular pillars	The greatest of the following: (a) $t = \dfrac{P}{0{,}392d_p - 4{,}9l_e}$ mm $\left(t = \dfrac{P}{0{,}04d_p - 0{,}5l_e}\ mm\right)$ (b) $t = \dfrac{d_p}{40}$ mm (c) t = 5,5 mm where $L < 90$ m, or = 7,5 mm where $L \geq 90$ m
	(3) Minimum wall thickness of hollow rectangular pillars or web plate thickness of I or channel sections	The lesser of the following: (a) $t = \dfrac{b\,r}{600l_e}$ mm (b) $t = \dfrac{b}{55}$ mm but to be not less than t = 5,5 mm where $L < 90$ m, or = 7,5 mm where $L \geq 90$ m
	(4) Minimum thickness of flanges of angle or channel sections	The lesser of the following: (a) $t_f = \dfrac{b\,r}{200l_e}$ mm (b) $t_f = \dfrac{b}{18}$ mm
	(5) Minimum thickness of flanges of built or rolled *I* sections	The lesser of the following: (a) $t_f = \dfrac{br}{400l_e}$ mm (b) $t_f = \dfrac{b}{36}$ mm

NOTE

As a first approximation, A_p may be taken as $\dfrac{\sqrt{k}\,P}{9{,}32}$ $\left(\dfrac{\sqrt{k}\,P}{0{,}95}\right)$ and the radius of gyration estimated for a suitable section having this area.

If the area calculated using this radius of gyration differs by more than 10 per cent from the first approximation, a further calculation using the radius of gyration corresponding to the mean area of the first and second approximation is to be made.

Table 6.4.5 Non-watertight pillar bulkheads

Symbols	Parameter	Requirement
d_w, t_p, b, c as defined in Ch 3,3.2 r = radius of gyration, in mm, of stiffener and attached plating = $10\sqrt{\dfrac{I}{A}}$ mm for rolled, built or swedged stiffeners = $d_w\sqrt{\dfrac{3\,b+c}{12\,(b+c)}}$ mm for symmetrical corrugation s = spacing of stiffeners, in mm I = moment of inertia, in cm^4, of stiffener and attached plating A = cross-sectional area, in cm^2, of stiffener and attached plating $A_1 = \dfrac{P}{12{,}36 - 51{,}5\,\dfrac{l_e}{r}}$ cm^2 $\left(A_1 = \dfrac{P}{1{,}26 - 5{,}25\,\dfrac{l_e}{r}}\text{ cm}^2\right)$ As a first approximation A_1 may be taken as $\dfrac{P}{9{,}32}\left(\dfrac{P}{0{,}95}\right)$ $A_2 = \dfrac{P}{4{,}9 - 14{,}7\,\dfrac{l_e}{r}}$ cm^2 $\left(A_2 = \dfrac{P}{0{,}5 - 1{,}5\,\dfrac{l_e}{r}}\text{ cm}^2\right)$ As a first approximation A_2 may be taken as $\dfrac{P}{3{,}92}\left(\dfrac{P}{0{,}4}\right)$ P, l_e as defined in Table 6.4.4 $\lambda = \dfrac{b}{c}$	(1) Minimum thickness of bulkhead plating	5,5 mm
	(2) Maximum stiffener spacing	1500 mm
	(3) Minimum depth of stiffeners or corrugations	75 mm
	(4) Cross-sectional area (including plating) for rolled, built or swedged stiffeners supporting beams, longitudinals, girders or transverses	(a) Where $\dfrac{s}{t} \le 80$ $A = A_1$ (b) When $\dfrac{s}{t} \ge 120$ $A = A_2$ (c) Where $80 < \dfrac{s}{t} < 120$ A is obtained by interpolation between A_1 and A_2
	(5) Cross-sectional area (including plating) for symmetrical corrugation	(a) Where $\dfrac{b}{t_p} \le \dfrac{750\lambda\, l_e}{(\lambda + 0{,}25)\, r}$ $A = A_1$ (b) When $\dfrac{b}{t_p} > \dfrac{750\lambda\, l_e}{(\lambda + 0{,}25)\, r}$ $A = A_2$

■ *Section 5* Helicopter landing areas

5.1 General

5.1.1 This Section gives the requirements for decks intended for helicopter operations on all unit types.

5.1.2 Attention is drawn to the requirements of National and other Authorities concerning the construction of helicopter landing platforms and the operation of helicopters as they affect the unit. These include the 2009 IMO MODU Code and SOLAS Chapter II-2 Regulation 18 and Chapter III Regulation 28, as applicable. Guidance on the provision and operation of helicopter landing or winching facilities may be drawn from international Standards such as the *International Chamber of Shipping (ICS) Guide to Helicopter/Ship Operations* and the *International Aeronautical Search and Rescue Manual (IAMSAR)*.

5.1.3 Where helicopter decks are positioned so that they may be subjected to wave impacts, the scantlings are to be considered in a realistic manner and increased to the satisfaction of LR.

5.1.4 Where the landing area forms part of a weather or erection deck, the scantlings are to be not less than those required for decks in the same position.

5.2 Plans and data

5.2.1 Plans and data are to be submitted giving the arrangements, scantlings and details of the helicopter deck. The type, size and weight of helicopters to be used are also to be indicated.

5.2.2 Relevant details of the largest helicopters, for which the deck is designed, are to be stated in the Operations Manual.

5.3 Arrangements

5.3.1 The landing area is to comply with applicable Regulations, International Standards or to the satisfaction of the National Authority, with respect to size, landing and take-off sectors of the helicopter, freedom from height obstructions, deck markings, safety nets and lighting, etc.

5.3.2 The landing area is to have an overall coating of non-slip material or other arrangements are to be provided to minimise the risk of personnel or helicopters sliding off the landing area.

5.3.3 A drainage system is to be provided in association with a perimeter guttering system or slightly raised kerb to prevent spilled fuel falling on to other parts of the unit. The drains are to be led to a safe area.

5.3.4 A sufficient number of tie-down points are to be provided to secure the helicopter.

5.3.5 Engine and boiler uptake arrangements are to be sited such that exhaust gases cannot be drawn into helicopter engine intakes during helicopter take-off or landing operations.

5.4 Landing area plating

5.4.1 The deck gross plate thickness, *t*, within the landing area is to be not less than:

$$t = t_1 + 1{,}5 \text{ mm}$$

where

$$t_1 = \frac{\alpha s}{1000\sqrt{k}} \text{ mm}$$

α = thickness coefficient obtained from Fig. 6.5.1

β = tyre print coefficient used in Fig. 6.5.1

$$= \log 10 \left(\frac{P_1 k^2}{s^2} \times 10^7 \right)$$

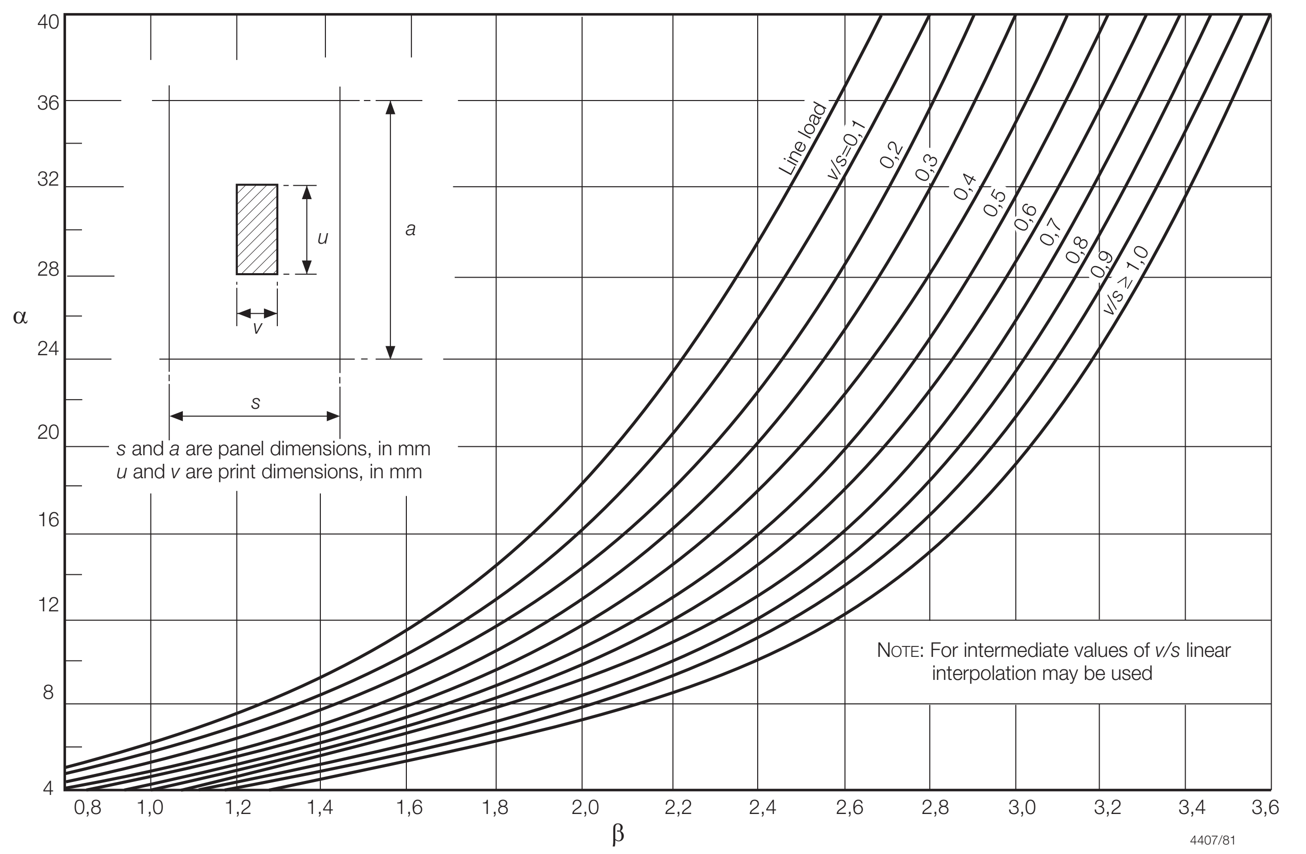


Fig. 6.5.1 Tyre print chart

The plating is to be designed for the emergency landing case taking:

$P_1 = 2{,}5\phi_1\,\phi_2\,\phi_3\,f\,\gamma\,P_w$ tonnes

where

ϕ_1, ϕ_2, ϕ_3 are to be determined from Table 6.5.3

f = 1,15 for landing decks over manned spaces, e.g., deckhouses, bridges, control rooms, etc.
= 1,0 elsewhere

P_h = the maximum all up weight of the helicopter, in tonnes

P_w = landing load on the tyre print, in tonnes;
For helicopters with a single main rotor, P_w, is to be taken as P_h divided equally between the two main undercarriage wheels.
For helicopters with tandem main rotors, P_w, is to be taken as P_h distributed between all main undercarriage wheels in proportion to the static loads they carry.
For helicopters fitted with landing gear consisting of skids, P_w is to be taken as P_h distributed in accordance with the actual load distribution given by the airframe manufacturer. If this is unknown, P_w is to be taken as 1/6 P_h for each of the two forward contact points and 1/3 P_h for each of the two aft contact points. The load may be assumed to act as a 300 mm x 10 mm line load at each end of each skid when applying Fig. 6.5.1.

γ = 0,6 generally. Factor to be specially considered where the helicopter deck contributed to the overall strength of the unit

Other symbols used in this Section are defined in Section 6 and in the appropriate sub-Section.

For wheeled undercarriages, the tyre print dimensions specified by the manufacturer are to be used for the calculation. Where these are unknown, it may be assumed that the print area is 300 x 300 mm and this assumption is to be indicated on the submitted plans.
For skids and tyres with an asymmetric print, the print is to be considered oriented both parallel and perpendicular to the longest edge of the plate panel and the greatest corresponding value of α taken from Fig. 6.5.1.

5.4.2 The plate thickness for aluminium decks is to be not less than:

$t = 1{,}4t_1 + 1{,}5$ mm

where

t_1 is the mild steel thickness as determined from 5.4.1.

Where the deck is fabricated using extruded sections with closely spaced stiffeners the plate thickness may be determined by direct calculations but the minimum deck thickness is to include 1,5 mm wear allowance. If the deck is protected by closely spaced grip/wear treads the wear allowance may be omitted.

5.5 Deck stiffening and supporting structure

5.5.1 The helicopter deck stiffening and the supporting structure for helicopter decks are to be designed for the load cases given in Table 6.5.1 in association with the permissible stresses given in Table 6.5.2. The helicopter is to be positioned so as to produce the most severe loading condition for each structural member under consideration.

Table 6.5.1 Design load cases for deck stiffening and supporting structure

Load cases	Load			
	Landing area		Supporting structure *See* Note 1	
	UDL, in kN/m^2	Helicopter patch load *See* Note 2	Self-weight	Horizontal load *See* Note 2
(1) Overall distributed loading	2	—	—	—
(2) Helicopter emergency landing	0,5	$2{,}5P_w f$	W_h	$0{,}5P_h$
(3) Normal usage	0,5	$1{,}5P_w$	W_h	$0{,}5P_h + 0{,}5W_h$

Symbols

P_h, P_w and f as defined in 5.4.1
UDL = uniformly distributed vertical load over entire landing area
W_h = structural self-weight of helicopter platform

NOTES
1. For the design of the supporting structure for helicopter platforms applicable self-weight and horizontal loads are to be added to the landing area loads.
2. The helicopter is to be so positioned as to produce the most severe loading condition for each structural member under consideration.

Table 6.5.2 Permissible stresses for deck stiffening and supporting structure

Load case *See* Table 6.5.1	Permissible stresses, in N/mm^2			
	Deck secondary structure (beams, longitudinals, *See* Notes 1 and 2)	Primary structure (transverses, girders, pillars, trusses)		All structure
	Bending		Combined bending and axial	Shear
(1) Overall distributed loading	$\dfrac{147}{k}$	$\dfrac{147}{k}$	$0{,}6\sigma_c$	$\dfrac{\text{Bending}}{\sqrt{3}}$
(2) Helicopter emergency landing	$\dfrac{245}{k}$	$\dfrac{220{,}5}{k}$	$0{,}9\sigma_c$	
(3) Normal usage	$\dfrac{176}{k}$	$\dfrac{147}{k}$	$0{,}6\sigma_c$	

Symbols

k = a material factor:
= as defined in Ch 2,1.2 for steel members
= k_a as defined in Ch 2,1.3 for aluminium alloy members

σ_c = yield stress, 0,2% proof stress or critical compressive buckling stress, in N/mm^2, whichever is the lesser

NOTES
1. Lower permissible stress levels may be required where helideck girders and stiffening contribute to the overall strength of the unit. Special consideration will be given to such cases.
2. When determining bending stresses in secondary structure, for compliance with the above permissible stresses, 100% end fixity may be assumed.

Table 6.5.3 Deck plate thickness calculation

Symbols	Expression
a, *s*, *u* and *v* as defined in Fig. 6.5.1 P_w = load, in tonnes, on the tyre print. For closely spaced wheels the shaded area shown in Fig. 6.5.1 may be taken as the combined print ϕ_1 = patch aspect ratio correction factor ϕ_2 = panel aspect ratio correction factor ϕ_3 = wide patch load factor	$\phi_1 = \dfrac{2v_1 + 1{,}1s}{u_1 + 1{,}1s}$ $v_1 = v$, but $\ngtr s$; $u_1 = u$, but $\ngtr a$ $\phi_2 = 1{,}0$ for $u \le (a - s)$ $= \dfrac{1}{1{,}3 - \dfrac{0{,}3}{s}(a-u)}$ for $a \ge u > (a - s)$ $= 0{,}77\dfrac{a}{u}$ for $u > a$ $\phi_3 = 1{,}0$ for $v < s$ $= 0{,}6\dfrac{s}{v} + 0{,}4$ for $1{,}5 > \dfrac{v}{s} > 1{,}0$ $= 1{,}2\dfrac{s}{v}$ for $\dfrac{v}{s} \ge 1{,}5$

5.5.2 In addition to the requirements of 5.5.1, the structure supporting helicopter decks is to be designed to withstand the loads imposed on the structure due to the motions of the unit. For self-elevating units, the motions are not to be less than those defined for transit conditions in Ch 4,3.10 and 3.11. The stress levels are to comply with load case 3 in Table 6.5.2, *see also* 5.1.3.

5.5.3 For load cases (1) and (2) in Table 6.5.1 the minimum moment of inertia, I, of aluminium alloy secondary structure stiffening is to be not less than:

$$I = \frac{5,25}{k_a} Z\, l_e \text{ cm}^4$$

where

Z is the required section modulus of the aluminium alloy stiffener and attached plating and k_a as defined in Ch 2,1.3.

5.5.4 Where a grillage arrangement is adopted for the platform stiffening, it is recommended that direct calculation procedures be used.

5.5.5 When the deck is constructed of extruded aluminium alloy sections, the scantlings will be specially considered on the basis of this Section.

5.6 Stowed helicopters

5.6.1 In addition to the requirements of 5.4 and 5.5, when arrangements are made to stow helicopters secured to the deck in predetermined positions, the structure is to be designed for the local loadings which can occur during normal operations.

5.6.2 Local loads on the structure are to be based on the maximum design undercarriage loadings specified by the helicopter manufacturer multiplied by a dynamic amplification factor based on the predicted motions of the unit as applicable. The self weight of the helicopter deck is to be included in the loadings imposed on the primary support structure. The permissible stress levels are to be in accordance with load case 3 in Table 6.5.2.

5.6.3 When the minimum design air temperature of the unit is 0°C or below, and considering the loadings in 5.6.2, the helicopter deck is to be assumed loaded with a uniformly distributed load of 0,5 kN/m^2 (0,05 tonne-f/m^2) to represent wet snow or ice.

5.7 Bimetallic connections

5.7.1 Where aluminium alloy platforms are connected to steel structures, details of the arrangements in way of the bimetallic connections are to be submitted.

■ *Section 6* Decks loaded by wheeled vehicles

6.1 General

6.1.1 Where it is proposed to use wheeled vehicles such as fork lift trucks and mobile cranes on deck structures, the deck plating and the supporting structure are to be designed on the basis of the maximum loading to which they may be subjected in service and the minimum gross scantlings are to comply with the requirements of Pt 3, Ch 9,3 of the Rules for Ships. In no case, however, are the scantlings to be less than would be required by the remaining requirements of this Chapter when the deck is considered as a weather deck or storage deck, as appropriate.

■ *Section 7* Bulkheads

7.1 General

7.1.1 This Section is applicable to watertight and deep tank transverse and longitudinal bulkheads, watertight flats, trunks and tunnels of column-stabilised units and self-elevating units. Requirements are also given for non-watertight bulkheads.

7.1.2 For surface type units *see* Ch 4.4.

7.1.3 The requirements of this Section apply to a vertical system of stiffening on bulkheads. They may also be applied to a horizontal system of stiffening provided that equivalent end support and alignment are provided.

7.1.4 The number and disposition of watertight bulkheads are to be in accordance with Ch 3,5 and the requirements of Chapter 7 regarding watertight integrity are to be complied with.

7.1.5 The buckling requirements of Ch 5,4 are also to be satisfied.

7.1.6 The height of the air and overflow pipes are to be clearly indicated on the plans submitted for approval and the load heads for scantlings are to be not less than those defined in Table 6.7.1.

Table 6.7.1 Watertight and deep tank bulkhead scantlings

Item and requirement	Watertight bulkheads	Deep tank bulkheads
(1) Plating thickness for plane, symmetrically corrugated and double plate bulkheads	$t = 0{,}004sf\sqrt{h_4 k}$ mm but not less than 5,5 mm	$t = 0{,}004s\,f\sqrt{\dfrac{\rho\, h_4\, k}{1{,}025}} + 2{,}5$ mm nor less than 7,5 mm
	In the case of symmetrical corrugations, s is to be taken as b or c in Fig. 3.3.1 in Chapter 3, whichever is the greater	
(2) Modulus of rolled and built stiffeners, swedges, double plate bulkheads and symmetrical corrugations	$Z = \dfrac{s\,k\,h_4\,l_e^2}{71\gamma\,(\omega_1 + \omega_2 + 2)}$ cm^3	$Z = \dfrac{\rho\,s\,k\,h_4\,l_e^2}{22\gamma\,(\omega_1 + \omega_2 + 2)}$ cm^3
	In the case of symmetrical corrugations, s is to be taken as p, *see also* Note 2	
(3) Inertia of rolled and built stiffeners and swedges	—	$I = \dfrac{2{,}3}{k}\,l_e Z$ cm^3
(4) Symmetrical corrugations and double plate bulkheads	Additional requirements to be complied with as detailed in Table 6.7.2	
(5) Stringers or webs supporting vertical or horizontal stiffening (a) Modulus	$Z = 5{,}5k\,h_4 S\,l_e^2$ cm^3	$Z = 11{,}7\rho\,k\,h_4\,S\,l_e^2$ cm^3
(b) Inertia	—	$I = \dfrac{2{,}5}{k}\,l_e Z$ cm^3

Symbols

s, S, I, k, ρ as defined in 7.2.1

d_w = web depth of stiffening member, in mm

f = $1{,}1 - \dfrac{s}{2500S}$ but not to be taken greater than 1,0

h_4 = load head, in metres measured vertically as follows:

(a) For watertight bulkhead plating, the distance from a point one-third of the height of the plate above its lower edge to a point 0,91 m above the bulkhead deck at side or to the worst damage waterline, whichever is the greater

(b) For tank bulkhead plating, the distance from a point one-third of the height of the plate above its lower edge to the top of the tank, or half the distance to the top of the overflow, whichever is the greater

(c) For watertight bulkhead stiffeners or girders, the distance from the middle of the effective length to a point 0,91 m above the bulkhead deck at side or to the worst damage waterline, whichever is the greater

(d) For tank bulkhead stiffeners or girders, the distance from the middle of the effective length to the top of the tank, or half the distance to the top of the overflow, whichever is the greater

l_e = effective length of stiffening member, in metres, and for bulkhead stiffeners, to be taken as $l - e_1 - e_2$, *see also* Fig. 6.7.1

p = spacing of corrugations as shown in Fig. 3.3.1 in Chapter 3

γ = 1,4 for rolled or built sections and double plate bulkheads
= 1,6 for flat bars
= 1,1 for symmetrical corrugations of deep tank bulkheads
= 1,0 for symmetrical corrugations of watertight bulkheads

ω, e = as defined in Table 6.7.3, *see also* Fig. 6.7.1

NOTES

1. In no case are the scantlings of deep tank bulkheads to be less than the requirements for watertight bulkheads where the boundary bulkheads of the tanks form part of the watertight sub-division of the unit to meet damage stability requirements, *see* Ch 3,5.
2. For self-elevating units, the bulkhead deck is to be taken as the freeboard deck.
3. For column-stabilised units, the bulkhead deck is, in general, to be taken as the uppermost continuous strength deck unless agreed otherwise with LR.
4. The scantlings of all void compartments adjacent to the sea are also to comply with 7.5.1.
5. In calculating the actual modulus of symmetrical corrugations the panel width b is not to be taken greater than that given by Ch 3,3.2.
6. For rolled or built stiffeners with flanges or face plates, the web thickness is to be not less than $\dfrac{d_w}{60\sqrt{k}}$ whilst for flat bar stiffeners the web thickness is to be not less than $\dfrac{d_w}{18\sqrt{k}}$.

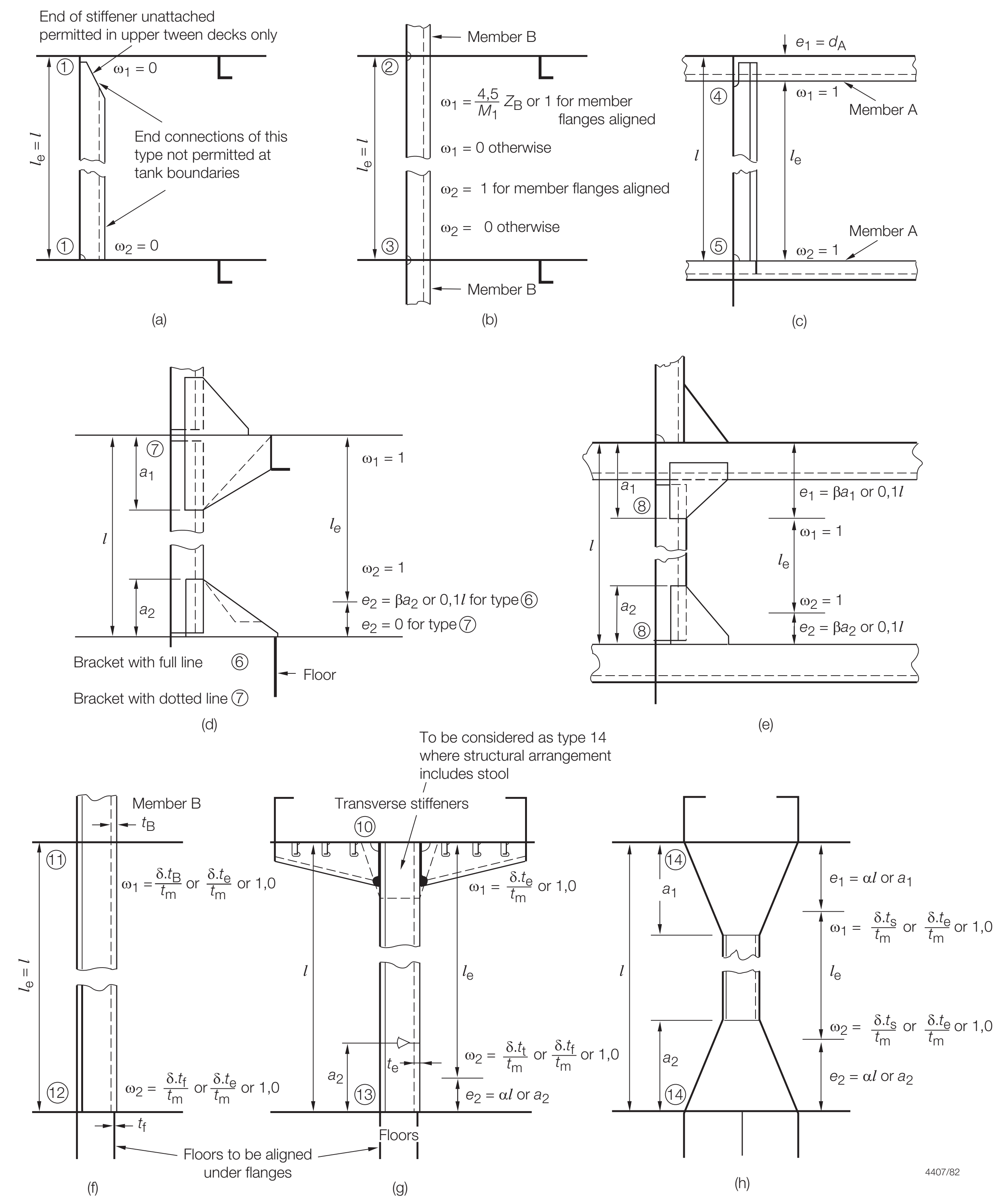


Fig. 6.7.1 Effective length and end constraint definitions for bulkheads

Table 6.7.2 Symmetrical corrugations and double plate bulkheads (additional requirements)

<table>
<tr><th>Symbols</th><th>Type of bulkhead</th><th>Parameter</th><th>Watertight bulkheads</th><th>Deep tank bulkheads</th></tr>
<tr><td rowspan="4">s, k as defined in 6.2.1
b = panel width as shown in Fig. 3.3.1 in Chapter 3
d = depth, in mm, of symmetrical corrugation or double plate bulkhead
l_e as defined in Table 6.7.1
A_w = shear area, in cm^2, of webs of double plate bulkhead
θ = angle of web corrugation to plane of bulkhead</td><td rowspan="4">Symmetrically corrugated, see also Notes 1 and 2</td><td rowspan="2">$\frac{b}{t}$</td><td>Not to exceed:
$85\sqrt{k}$ at top, and
$70\sqrt{k}$ at bottom</td><td>Not to exceed:
$70\sqrt{k}$ at top and bottom</td></tr>
<tr><td colspan="2">See also Note 4</td></tr>
<tr><td>d</td><td>—</td><td>To be not less than:
$39 l_e$ mm</td></tr>
<tr><td>θ</td><td colspan="2">To be not less than 40°</td></tr>
<tr><td rowspan="4">NOTES
1. The plating thickness at the middle of span l_e of corrugated or double plate bulkheads is to extend not less than $0{,}2 l_e$ m above mid-span.
2. Where the span of corrugations exceeds 15 m, a diaphragm plate is to be arranged at about mid-span.
3. See also Chapter 8.
4. In calculating the actual modulus of symmetrical corrugations, the panel width b is not to be taken greater than that given by Ch 3,3.2.</td><td rowspan="4">Double plate, see also Note 3</td><td>$\frac{s}{t}$</td><td colspan="2">Not to exceed: $75\sqrt{k}$ at top, and
$65\sqrt{k}$ at bottom</td></tr>
<tr><td>$\frac{d}{t_w}$</td><td colspan="2">Not to exceed: $85\sqrt{k}$ at top, and
$75\sqrt{k}$ at bottom</td></tr>
<tr><td>d</td><td>—</td><td>To be not less than:
$39 l_e$ mm</td></tr>
<tr><td>A_w</td><td>To be not less than:
$\frac{0{,}12Z}{l_e}$ cm^2 at top, and
$\frac{0{,}18Z}{l_e}$ cm^2 at bottom</td><td>$\frac{0{,}07Z}{l_e}$ cm^2 at top, and
$\frac{0{,}10Z}{l_e}$ cm^2 at bottom</td></tr>
</table>

7.2 Symbols

7.2.1 The following symbols are applicable to this Section:

k = higher tensile steel factor, *see* Ch 2,1
s = spacing of secondary stiffeners, in mm
I = inertia of stiffening member, in cm4, *see* Ch 3,3
S = spacing or mean spacing of primary members, in metres
Z = section modulus of stiffening member, in cm^3, *see* Pt 3, Ch 3,3
ρ = relative density (specific gravity) of liquid carried in a tank, but is not to be taken less than 1,025.

7.3 Watertight and deep tank bulkheads

7.3.1 The scantlings of watertight and deeptank bulkheads are to comply with the requirements of Tables 6.7.1 to 6.7.3. Where tanks cannot be inspected at normal periodic surveys, the scantlings derived from this Section are to be suitably increased.

7.3.2 Where bulkhead stiffeners support deck girders, transverses or pillars over, the scantlings are to satisfy the requirements of Section 4.

7.3.3 The strength of bulkheads and flats which support the ends of bracings or columns will be specially considered.

7.3.4 In way of partially filled tanks, the scantlings and structural arrangements of the boundary bulkheads are to be capable of withstanding the loads imposed by the movement of the liquid in those tanks. The magnitude of the predicted loadings, together with the scantling calculations, may require to be submitted, *see also* Ch 3,4.18.

7.3.5 In deep tanks, oil fuel or other liquids are to have a flash point of 60°C or above (closed-cup test). Where tanks are intended for liquids of a special nature, the scantlings and arrangements will be specially considered in relation to the properties of the liquid, *see* 7.3.6. For the scantlings of mud tanks, *see* 7.6.

7.3.6 Where tanks are intended for the storage of oil with a flash point less than 60°C (closed-cup test) the scantlings of bulkheads on surface-type units are to comply with Ch 4,4, but other unit types are to comply with this Section. The minimum scantlings and arrangements on all units are also to comply with Pt 3, Ch 3.

7.3.7 For cofferdams on units with oil storage tanks, as defined in 7.3.6, the separation of tanks and spaces are to comply with Pt 3, Ch 3. Cofferdams are to be fitted between tanks as necessary, depending on the liquids stored. In general, cofferdams are to be fitted between tanks in accordance with the requirements of Ch 3,5.

Table 6.7.3 Bulkhead end constraint factors (*see continuation*)

Type	End connection, *see* Fig. 6.7.1			ω	e	μ
Rolled or built stiffeners and swedges						
1	End of stiffeners unattached or attached to plating only			0	0	—
2	Members with webs and flanges (or bulbs) in line and attached at deck or horizontal girder *See also* Note 1	Adjacent member of B of smaller modulus		The lesser of $\dfrac{4,5Z_B}{M_1}$ or 1,0	0	—
3		Adjacent member B of same or larger modulus		1,0	0	—
4	Bracketless connection to longitudinal member	Member A within length l		1,0	$\dfrac{d_A}{1000}$	—
5		Member A outside length l		1,0	0	—
6	Bracketed connection	To transverse member	Bracket extends to floor	1,0	The lesser of βa or $0,1l$	—
7			Otherwise	1,0	0	—
8		To longitudinal member		1,0	The lesser of βa or $0,1l$	—
Symmetrical corrugations or double plate bulkheads						
9	Welded directly to deck – no bulk-head in line	No longitudinal brackets		0	0	—
10		With longitudinal brackets and trans-verse stiffeners supporting corrugated bulkhead		The lesser of $\dfrac{\delta t_e}{t_m}$ or 1,0	0	—
11	Welded directly to deck or girder	Bulkhead B, having same section, in line		The least of $\dfrac{\delta t_B}{t_m}$ or $\dfrac{\delta t_e}{t_m}$ or 1,0	0	—
12	Welded directly to tank top and effectively supported by floors in line with each bulkhead flange, *see also* Note 2	Thickness at bottom same as that at mid-span		The least of $\dfrac{\delta t_f}{t_m}$ or $\dfrac{\delta t_e}{t_m}$ or 1,0	0	—
13		Thickness at bottom greater than that at mid-span		The least of $\dfrac{\delta t_f}{t_m}$ or $\dfrac{\delta t_e}{t_m}$ or 1,0	The lesser of αl or a	The least of $\dfrac{\delta t_f}{t_m}$ or $\dfrac{\delta t_e}{t_m}$ or 1,0
14	Welded to stool efficiently supported by the unit's structure			For deep tank bulkheads 1,0 For watertight bulkheads the least of $\dfrac{\delta t_f}{t_m}$ or $\dfrac{\delta t_e}{t_m}$ or 1,0	The lesser of αl or a	$\dfrac{10Z_s}{M_2}$

Table 6.7.3 Bulkhead end constraint factors (*conclusion*)

Symbols

s, l, ρ, k, as defined in 7.2.1

a = height, in metres, of bracket or end stool or lowest strake of plating of symmetrically corrugated or double plate bulkheads, *see* Fig. 6.7.1

d_A = web overall depth, in mm, of adjacent member A

e = effective length, in metres, of bracket or end stool, *see* Fig. 6.7.1

h_o = h_4 but measured from the middle of the overall length l

l_e, p, h_4 as defined in Table 6.7.1

t_f = thickness of supporting floor, in mm

t_m, t_e = thickness, in mm, of flange plating of corrugation or double plate bulkhead at mid-span or end, respectively

t_s = thickness, in mm, of stool adjacent to bulkhead

t_B = thickness, in mm, of flange plating of member B

Subscripts 1 and 2, when applied to ω, e and a, refer to the top and bottom ends of stiffener respectively

$M_1 = \dfrac{h_4 \, s \, l_e^2}{71}$ for watertight bulkheads

$= \dfrac{\rho \, h_4 \, s \, l_e^2}{22}$ for deep tank bulkheads

$M_2 = \dfrac{h_o \, s \, l^2}{71}$ for watertight bulkheads

$= \dfrac{\rho h_o \, s \, l^2}{22}$ for deep tank bulkheads

In the case of symmetrical corrugations $s = p$

Z_s = section modulus, in cm^3, of horizontal section of stool adjacent to deck or tank top over breadth s or p (as applicable)
All material which is continuous from top to bottom of stool may be included in the calculation

Z_B = section modulus, in cm^3, of adjacent member B

α = a factor depending on μ and determined as follows:
where $\mu \leq 1,0$ $\quad \alpha = 0$
where $\mu > 1,0$ $\quad \alpha = 0,5 - \dfrac{1}{\sqrt{2\mu + 2}}$

β = a factor depending on the end bracket stiffening and to be taken as:
1,0 for brackets with face bars directly connected to stiffener face bars
0,7 for flanged brackets
0,5 for unflanged brackets

δ = 1,0 generally

$\delta = \dfrac{0,932 \sqrt{k}}{\xi}$ for corrugated watertight bulkheads

η = lesser of 1,0 and $\dfrac{50 t_m \sqrt{k}}{b}$ for welded sections

η = lesser of 1,0 and $\dfrac{60 t_m \sqrt{k}}{b}$ for cold formed sections

μ = a factor representing end constraint for symmetrical corrugation and double plate bulkheads

ξ = 1,0 where full continuity of corrugation webs is provided at the ends

ξ = greater of 1,0 and (η + 0,333) where full continuity is not provided

ω = an end constraint factor relating to the different types of end connection, *see* Fig. 6.7.1

NOTES
1. Where the end connection is similar to type 2 or 3, but member flanges (or bulbs) are not aligned and brackets are not fitted, $\omega = 0$.
2. Where the end connection is similar to type 12 or 13, but a transverse girder is arranged in place of one of the supporting floors, special consideration will be required.

7.3.8 Where watertight bulkhead stiffeners are cut in way of watertight doors in the lower part of a bulkhead, the opening is to be suitably framed and reinforced. Where stiffeners are not cut but the spacing between the stiffeners is increased on account of watertight doors, the stiffeners at the sides of the doorways are to be increased in depth and strength so that the efficiency is at least equal to that of the unpierced bulkhead, without taking the stiffness of the door frame into consideration. Watertight recesses in bulkheads are generally to be so framed and stiffened as to provide strength and stiffness equivalent to the requirements for watertight bulkheads.

7.3.9 Wash bulkheads or divisions are to be fitted to deep tanks as required by Ch 7,4. The division bulkhead may be intact or perforated as desired. If intact, the scantlings are to be as required for boundary bulkheads. If perforated, the plating thickness is not to be less than 7,5 mm and the modulus of the stiffeners may be 50 per cent of that required for boundary bulkheads, using h_4 measured to the crown of the tank. The stiffeners are to be bracketed at top and bottom. The area of perforation is to be not less than five per cent nor more than 10 per cent of the total area of the bulkhead. Where brackets from horizontal girders on the boundary bulkheads terminate at the centreline bulkhead, adequate support and continuity are to be maintained.

7.3.10 The scantlings of end brackets fitted to bulkhead stiffeners are, in general, to comply with Chapter 8.

7.4 Watertight flats, trunks and tunnels

7.4.1 The scantlings and arrangements of watertight flats, trunks and tunnels are to be equivalent to the requirements for watertight bulkheads or tanks as defined in 7.3 as appropriate. The scantlings of shaft tunnels will be specially considered. The scantlings at the crown or bottom of tanks are to comply with the requirements of Table 6.4.1.

7.4.2 Additional strengthening is to be fitted to tunnels under the heels of pillars, as necessary.

7.5 Watertight void compartments

7.5.1 In all units where watertight void compartments are adjacent to the sea, the scantlings of the boundary bulkheads are to be determined from Table 6.7.1 for watertight bulkheads but the scantlings are not to be less than required for tank bulkheads using the load head h_4, measured to the maximum operating draught of the unit.

7.6 Mud tanks

7.6.1 The scantlings of mud tanks are to be not less than those required for tanks using the design density of mud. However, in no case is the relative density of wet mud to be taken as less than 2,2 unless agreed otherwise with LR.

7.7 Non-watertight bulkheads

7.7.1 The scantlings of non-watertight bulkheads supporting decks are to be in accordance with Table 6.4.5.

■ *Section 8* Double bottom structure

8.1 Symbols and definitions

8.1.1 The symbols used in this Section are defined as follows:

L, T_0 and T_T as defined in Ch 1,5

B as defined in Ch 1,5 but need not exceed B_1

B_1 = maximum distance between longitudinal bulkheads, in metres

d_{DB} = Rule depth of centre girder, in mm

d_{DBA} = actual depth of centre girder, in mm

h_{DB} = head from top of inner bottom to top of overflow pipe, in metres

h_4 = load head as defined in Table 6.7.1

s = spacing of stiffeners, in mm.

8.2 General

8.2.1 In general, double bottoms need not be fitted in non-propelled units and column-stabilised units, except where required by a National Administration.

8.2.2 Where double bottoms are fitted on self-elevating units or column-stabilised units, the scantlings are to comply with this Section. For surface-type units, *see* Ch 4,4.

8.2.3 The requirements in this Section are, in general, applicable to double bottoms with stiffeners fitted parallel to the hull bending compressive stress. When other stiffening arrangements are proposed the scantlings will be specially considered, but the minimum requirements of this Section are to be complied with.

8.2.4 The arrangements of drainage wells, recesses and dump valves in the double bottom will be specially considered.

8.2.5 If it is intended to dry-dock the unit, girders and the side walls of duct keels are to be continuous and the structure is to have adequate strength to withstand the forces imposed by dry-docking the unit.

8.2.6 Adequate access is to be provided to all parts of the double bottom. The edges of all holes are to be smooth. The size of the opening should not, in general, exceed 50 per cent of the double bottom depth, unless edge reinforcement is provided. In way of ends of floors and fore and aft girders at transverse bulkheads, the number and size of holes are to be kept to a minimum, and the openings are to be circular or elliptical. Edge stiffening may be required in these positions.

8.2.7 Provision is to be made for the free passage of air and water from all parts of tank spaces to the air pipes and suctions, account being taken of the pumping rates required. To ensure this, sufficient air holes and drain holes are to be provided in all longitudinal and transverse non-watertight primary and secondary members. The drain holes are to be located as close to the bottom as is practicable, and air holes are to be located as close to the inner bottom as is practicable, *see also* Pt 3, Ch 8.

8.3 Self-elevating units

8.3.1 When a double bottom is fitted to a self-elevating unit, the scantlings of the double bottom will be specially considered in accordance with Ch 4,3 but the general requirements of this Section are to be complied with.

8.3.2 The longitudinal extent of the double bottom will be specially considered in respect of the design and safety of the unit but it should extend as far forward and aft as is practicable. A double bottom need not be fitted in pre-load deep tanks or other wing deep tanks.

8.3.3 The depth of the double bottom at the centreline, d_{DB}, is to be in accordance with 8.3.4 and the inner bottom is, in general, to be continued out to the unit's side in such a manner as to protect the bottom to the turn of bilge. When pre-load wing deep tanks are fitted port and starboard, the inner bottom may be terminated at the deep tank longitudinal bulkheads.

8.3.4 **The centre girder** is to have a depth of not less than that given by:

$$d_{DB} = 28B + 205\sqrt{T_T} \text{ mm}$$

nor less than 760 mm. The centre girder thickness is to be not less than:

$$t = (0{,}008 d_{DB} + 4)\sqrt{k} \text{ mm}$$

nor less than 6,0 mm. The thickness may be determined using the value for d_{DB} without applying the minimum depth of 760 mm.

8.3.5 **Side girders** are to be fitted below longitudinal bulkheads. In general, one side girder is to be fitted where the breadth, *B*, exceeds 14 m and two side girders are to be fitted on each side of the centreline where *B* exceeds 21 m. Equivalent arrangements are to be provided where longitudinal bulkheads are fitted. The side girders are to extend as far forward and aft as practicable and are to have a thickness not less than:

$$t = (0{,}0075 d_{DB} + 1) \sqrt{k} \quad \text{mm}$$

nor less than 6,0mm. In general, a vertical stiffener, having a depth not less than 100 mm and a thickness equal to the girder thickness, is to be arranged midway between floors.

8.3.6 **Watertight side girders** are to have a plating thickness corresponding to the greater of the following:

(a) $t = (0{,}0075 d_{DB} + 2) \sqrt{k}$ mm, or

(b) Thickness, *t*, as for deep tanks, *see* 7.3, using the load head h_4 which, in the case of double bottom tanks which are interconnected to side tanks or cofferdams, is not to be less than the head measured to the highest point of the side tank or cofferdam.

8.3.7 If the depth of the watertight side girders exceeds 915 mm but does not exceed 2000 mm, the girders are to be fitted with vertical stiffeners spaced not more than 915 mm apart and having a section modulus not less than:

$$Z = 5{,}41 d_{DBA}{}^2 h_{DB} s k \times 10^{-9} \quad \text{cm}^3$$

The ends of the stiffeners are to be sniped. Where the double bottom tanks are interconnected with side tanks or cofferdams, or where the depth of the girder exceeds 2000 mm, the scantlings of watertight girders are to be not less than those required for deep tanks, *see* 7.3, and the ends of the stiffeners are to be bracketed top and bottom.

8.3.8 **Duct keels**, where arranged, are to have a thickness of side plates corresponding to the greater of the following:

(a) $t = (0{,}008 d_{DB} + 2) \sqrt{k}$ mm, or

(b) Thickness, *t*, as for deep tanks, *see* 7.3, using the load head h_4 which, in the case of double bottom tanks which are interconnected to side tanks or cofferdams, is not to be less than the head measured to the highest point of the side tank or cofferdam.

8.3.9 The sides of the duct keels are, in general, to be spaced not more than 2,0 m apart. Where the sides of the ducts keels are arranged on either side of the centreline or side girder, each side is, in general, to be spaced not more than 2,0 m from the centreline or side girder. The inner bottom and bottom shell within the duct keel are to be suitably stiffened. The primary stiffening in the transverse direction is to be suitably aligned with the floors in the adjacent double bottom tanks. Where the duct keels are adjacent to double bottom tanks which are interconnected with side tanks or cofferdams, the stiffening is to be in accordance with the requirements for deep tanks, *see* 7.3. Access to the duct keel is to be by watertight manholes or trunks.

8.3.10 **Inner bottom plating** is, in general, to have a thickness not less than:

$$t = 0{,}00136 (s + 660) \sqrt[4]{k^2 L T_T} \quad \text{mm}$$

nor less than 6,5 mm.

8.3.11 The thickness of the inner bottom plating as determined in 8.3.10 is to be increased by 10 per cent in machinery spaces but in no case is the thickness to be less than 7,0 mm.

8.3.12 A margin plate, if fitted, is to have a thickness throughout 20 per cent greater than that required for inner bottom plating.

8.3.13 Where the double bottom tanks are common with side tanks or cofferdams, the thickness of the inner bottom plating is to be not less than that required for deep tanks, *see* 7.3, and the load head h_4 is to be measured to the highest point of the side tank or cofferdam.

8.3.14 **Inner bottom stiffeners** are in general to have a section modulus not less than 85 per cent of the Rule value for bottom shell stiffeners, *see* 3.3.1. When the inner bottom design loading is considerably less than $9{,}82 T_T$ kN/m^2 (T_T tonne-f/m^2) the scantlings of the inner bottom stiffeners will be specially considered. Where the double bottom tanks are interconnected with side tanks or cofferdams, the scantlings are to be not less than those required for deep tanks, *see* 7.3.

8.3.15 **Plate floors** are to be fitted under heavy machinery items and under bulkheads and elsewhere at a spacing not exceeding 3,8 m. The thickness of non-watertight plate floors is to be not less than:

$$t = (0{,}009 d_{DB} + 1) \sqrt{k} \quad \text{mm}$$

nor less than 6,0 mm. The thickness need not be greater than 15 mm, but the ratio between the depth of the double bottom and the thickness of the floor is not to exceed $130\sqrt{k}$. This ratio may, however, be exceeded if suitable additional stiffening is fitted. Vertical stiffeners are to be fitted at each bottom shell stiffener, having a depth not less than 150 mm and a thickness equal to the thickness of the floors. For units of length, *L*, less than 90 m, the depth is to be not less than 1,65*L* mm, with a minimum of 50 mm.

8.3.16 **Watertight floors** are to have thickness not less than:

(a) $t = (0{,}008 d_{DB} + 3) \sqrt{k}$ mm, or

(b) $t = (0{,}009 d_{DB} + 1) \sqrt{k}$ mm,

whichever is the greater, but not to exceed 15 mm on floors of normal depth. The thickness is also to satisfy the requirements for deep tanks, *see* 7.3, with the load head h_4 measured to the highest point of the side tank or cofferdam if the double bottom tank is interconnected with these tanks. The scantlings of the stiffeners are to be in accordance with the requirements of 7.3 for deep tanks, but in no case is the modulus to be less than:

$$Z = 5{,}41 d_{DBA}{}^2 h_{DB} s k \times 10^{-9} \quad \text{cm}^3$$

Vertical stiffeners are to be connected to the inner bottom and shell stiffeners.

8.3.17 Between plate floors, transverse brackets having a thickness not less than $0{,}009d_{DB}$ mm are to be fitted, extending from the centre girder and margin plate to the adjacent longitudinal. The brackets, which are to be suitably stiffened at the edge, are to be fitted at every frame at the margin plate, and those at the centre girder are to be spaced not more than 1,25 m.

8.3.18 Where floors form the boundary of a sea inlet box, the thickness of the plating is to be the same as the adjacent shell, but not less than 12,5 mm. The scantlings of stiffeners, where required are, in general, to comply with 7.3 for deep tanks. Sniped ends for stiffeners on the boundaries of these spaces are to be avoided wherever practicable. The stiffeners should be bracketed or the free end suitably supported to provide alignment with backing structure.

8.4 Column-stabilised and sea bed-stabilised units

8.4.1 Where a double bottom is fitted in the lower hull of column-stabilised units or sea bed-stabilised units, the scantlings of the double bottom structure will be specially considered but the general requirements of 8.3 are to be complied with where applicable. The minimum scantlings of the double bottom structure are to be in accordance with 8.4.2.

8.4.2 The scantlings of tank boundaries are to comply with the requirements for tank bulkheads in Section 7 but the load head h4 is not to be taken less than the distance measured to T_0. When the internal double bottom compartment is a void space the scantlings of watertight boundaries are to comply with 7.5.1 and Table 6.7.1.

8.4.3 The boundaries of a sea inlet box are to comply with the requirements of 8.3.18.

8.4.4 The strength of the bottom structures in sea bed-stabilised units is also to comply with Ch 4,2.1.6.

■ *Section 9* Superstructures and deckhouses

9.1 General

9.1.1 The term 'erection' is used in this Section to include both superstructures and deckhouses.

9.1.2 This Section applies to erections on all types of units defined in Pt 3, Ch 2,2 except for erections on surface type units which are to be in accordance with Ch 4,4. Units with a Rule length, *L*, greater than 150 m will be specially considered.

9.1.3 The scantlings of exposed bulkheads and decks of deckhouses are generally to comply with the requirements of this Section, but increased scantlings may be required where the structure is subjected to local loadings greater than those defined in the Rules, *see also* 9.1.6. Where there is no access from inside the house to below the freeboard deck or into buoyant spaces included in stability calculations, or where a bulkhead is in a particularly sheltered location, the scantlings may be specially considered.

9.1.4 The scantlings of superstructures which form an extension of the side shell or which form an integral part of the unit's hull and contribute to the overall strength of the unit will be specially considered. The upper hull structure of column-stabilised units are to comply with Section 3.

9.1.5 Any exposed part of an erection which may be subject to immersion in damage stability conditions and which could result in down flooding is to have scantlings not less than required for watertight bulkheads given in Section 7.

9.1.6 The boundary bulkheads of accommodation spaces which may be subjected to blast loading are to comply with Ch 3,4 and permissible stress levels are to satisfy the factors of safety given in Ch 5,2.1.1(c).

9.1.7 The scantlings of erections used for helicopter landing areas are also to comply with Section 5.

9.1.8 For requirements relating to companionways, doors and hatches, *see* Chapter 7.

9.2 Symbols

9.2.1 The following symbols and definitions are applicable to this Chapter, unless otherwise stated:

L, B, T_T and C_b as defined in Ch 1,5.1.

- b = breadth of deckhouse, at the positions under consideration, in metres
- k = higher tensile steel factor, *see* Ch 2,1.2
- l_e = effective length, in metres, of the stiffening member, deck beam or longitudinal measured between span points, *see* Ch 3,3.3
- l_s = span, in metres, of erection stiffeners and is to be taken as the 'tween deck or house height but in no case less than 2,0 m
- s = spacing of stiffeners, beams or longitudinals, in mm
- s_b = standard spacing, in mm, of stiffeners, beams or longitudinals, and is to be taken as:
  - (a) for 0,05L from the ends: s_b = 610 mm or that required by (b), whichever is the lesser
  - (b) elsewhere: $s_b = 470 + 1{,}67L_2$ mm but forward of 0,2L from the forward perpendicular s_b is not to exceed 700 mm
- B_1 = actual breadth of unit at the section under consideration, measured at the weather deck, in metres
- L_2 = length of unit in metres, but need not be taken greater than 250 m
- L_3 = length of unit in metres, but need not be taken greater than 300 m

D = moulded depth of unit, in metres, to the uppermost continuous deck

X = distance, in metres, between the after perpendicular and the bulkhead under consideration. When determining the scantlings of deckhouse sides, the deckhouse is to be subdivided into parts of approximately equal length not exceeding 0,15L each, and X is to be measured to the mid-length of each part

α = a coefficient given in Table 6.9.1

$$\beta = 1,0 + \left(\frac{\left(\frac{X}{L} - 0,45\right)}{(C_b + 0,2)}\right)^2 \quad \text{for } \frac{X}{L} \leq 0,45$$

$$= 1,0 + 1,5\left(\frac{\left(\frac{X}{L} - 0,45\right)}{(C_b + 0,2)}\right)^2 \quad \text{for } \frac{X}{L} > 0,45$$

C_b is to be taken not less than 0,6 nor greater than 0,8. Where the aft end of an erection is forward of amidships, the value of C_b used for determining β for the aft end bulkhead is to be taken as 0,8

γ = vertical distance, in metres, from the maximum transit waterline to the mid-point of span of the bulkhead stiffener, or the mid-point of the plate panel, as appropriate

δ = 1,0 for exposed machinery casings and $\left(0,3 + 0,7\frac{b}{B_1}\right)$ elsewhere, but in no case to be taken less than 0,475

λ = a coefficient given in Table 6.9.2.

Table 6.9.1 Values of α

Position		α
Lowest tier	– unprotected front	$2,0 + 0,0083L_3$
Second tier	– unprotected front	$1,0 + 0,0083L_3$
Third tier and above All tiers All tiers	– unprotected front – protected fronts – sides	$0,5 + 0,0067L_3$
All tiers	– aft end where aft of amidships	$0,7 + 0,001L_3 - 0,8\frac{X}{L}$
All tiers	– aft end where forward of amidships	$0,5 + 0,001L_3 - 0,4\frac{X}{L}$

9.3 Definition of tiers

9.3.1 The first, or the lowest tier, is an erection situated on the deck to which D is measured. The second tier is the next tier above the lowest tier, and so on.

Table 6.9.2 Values of λ

Length L in metres	λ	Expression for λ
20 30 40 50 60 70 80 90 110 130 150	0,89 1,76 2,57 3,34 4,07 4,76 5,41 6,03 7,16 8,18 9,10	$L \leq 150$ m $\lambda = \left(\frac{L}{10}e^{-\frac{L}{300}}\right) - \left(1 - \left(\frac{L}{150}\right)^2\right)$
150 170 190 210 230 250 270 290 300	9,10 9,65 10,08 10,43 10,69 10,86 10,98 11,03 11,03	150 m $\leq L \leq$ 300 m $\lambda = \frac{L}{10}e^{-\frac{L}{300}}$
300 and above	11,03	$L \geq 300$ m $\lambda = 11,03$

9.3.2 For self-elevating units where the freeboard corresponding to the required summer moulded draught for the unit can be obtained by considering the unit to have a virtual moulded depth of at least one standard superstructure height less than the Rule depth, D, measured to the uppermost continuous deck, proposals to treat the first tier erection as a second tier, and so on, will be specially considered. The standard height of superstructure is the height defined in the *International Convention on Load Lines, 1966*.

9.4 Design pressure head

9.4.1 The design pressure head, h, to be used in the determination of erection scantlings is to be taken as:

$$h = \alpha\,\delta\,(\beta\,\lambda - \gamma) \text{ m}$$

9.4.2 In no case is the design pressure head to be taken as less than the following:

(a) Lowest tier of unprotected fronts:
minimum $h = 2,5 + 0,01L_2$ m

(b) All other locations:
minimum $h = 1,25 + 0,005L_2$ m

9.5 Bulkhead plating and stiffeners

9.5.1 The plating thickness, t, of fronts, sides and aft ends of all erections other than the sides of the superstructures where these are an extension of the side shell, is to be less than:

$t = 0{,}003s\sqrt{k\,h}$ mm,

but in no case is the thickness to be less than:

(a) for the lowest tier:
$t = (5{,}0 + 0{,}01L_3)\sqrt{k}$ mm,
but not less than 5,0 mm.

(b) for the upper tiers:
$t = (4{,}0 + 0{,}01L_3)\sqrt{k}$ mm,
but not less than 5,0mm.

9.5.2 The thickness of sides of forecastles, bridges and poops is to be as required by Ch 4,4.

9.5.3 The modulus of stiffeners, Z, on fronts, sides and end bulkheads of all erections, other than the sides of superstructures where these are an extension of the side shell, is to be not less than:

$Z = 0{,}0035h\,s\,l_s^2\,k$ cm^3

9.5.4 The end connections of stiffeners are to be as given in Table 6.9.3.

9.5.5 The section modulus of side frames of forecastles, bridges and poops is to be as required by Ch 4,4.

9.6 Erections on self-elevating units

9.6.1 The scantlings of exposed ends and sides of erections are to comply with 9,5, but the additional requirements of this sub-Section are to be complied with.

9.6.2 The plating thickness, t, of exposed lower tier fronts is to be not less than:

$t = 0{,}0036s\sqrt{k\,h}$ mm

but in no case is the thickness to be less than 7,0 mm.

9.6.3 The modulus of stiffeners, Z, on exposed lowest tier fronts is to be not less than:

$Z = 0{,}0044h\,s\,l_s^2\,k$ cm^3

9.6.4 Where the exposed side of an erection is close to the side shell of the unit, the scantlings may be required to conform to the requirements for exposed bulkheads of unprotected house fronts.

9.6.5 The scantlings of jackhouses will be specially considered, but are not to be less than the scantlings that would be required for an erection at the same location.

9.6.6 The end connections of stiffeners are to be as given in Table 6.9.3.

Table 6.9.3 Stiffener end connections

Position	Attachment at top and bottom
1. Front stiffeners of lower tiers and of upper tiers when L is 160 m or greater	*See* Chapter 8 *See* Note
2. Front stiffeners of upper tiers when L is less than 160 m	May be unattached
3. Side stiffeners of lower tiers where two or more tiers are fitted	Bracketed, unless stiffener modulus is increased by 20 per cent and ends are welded to the deck all round
4. Side stiffeners if only one tier is fitted, and aft end stiffeners of after deck-houses on deck to which D is measured	*See* Chapter 8
5. Side stiffeners of upper tiers where L is 160 m or greater	*See* Chapter 8
6. Side stiffeners of upper tiers when L is less than 160 m	May be unattached
7. Aft end stiffeners except as covered by item 4	May be unattached
8. Exposed machinery and pump-room casings. Front sitffeners on amid-ship casings and all stiffeners on aft end casings which are situated on the deck to which D is measured	Bracketed
9. All other stiffeners on exposed machinery and pump-room casings	6,5 cm^2 of weld
NOTE Front stiffeners of lower tiers on self-elevating units are to be bracketed.	

9.7 Erections on other unit types

9.7.1 Where the erection can be subjected to wave forces, the scantlings of exposed ends and sides of erections are to comply with 9.5.

9.7.2 When the erection is not subjected to wave forces in any condition then the structure is to be suitable for the maximum design loadings but the minimum scantlings of exposed sides and ends of all erections is to be not less than:

(a) for the lowest tier:
$t = (5{,}0 + 0{,}01L)\sqrt{k}$ mm, but not less than 5,0 mm.

(b) for the upper tiers:
$t = (5{,}0 + 0{,}01L)\sqrt{k}$ mm, but not less than 5,0 mm.

9.7.3 The modulus of stiffeners, Z, of exposed sides and ends of all erections is to be not less than:

$Z = 0{,}0035h\,s\,l_s^2\,k$ cm^3

where

$h = 1{,}25 + 0{,}005L$ m.

9.7.4 The end connections of stiffeners not subjected to wave loadings are to be as given in Table 6.9.4.

Table 6.9.4 Other unit types stiffener end connections

Position	Attachment at top and bottom
1. Side stiffeners of lower tiers where two or more tiers are fitted	Bracketed unless stiffener modulus is increased by 20 per cent and ends are welded to the deck all around
2. Side stiffeners if only one tier is fitted	*See* Chapter 8
3. All other stiffeners	May be unattached

9.8 Deck plating

9.8.1 In general, the thickness of erection deck plating is to be not less than that required by Table 6.9.5.

Table 6.9.5 Thickness of deck plating

Position	Thickness of deck plating, in mm		
	$L \leq 100$ m		$L > 100$ m
Top of first tier erection	$(5{,}5 + 0{,}02L)\sqrt{\dfrac{ks}{s_b}}$	but not less than 5,0 mm	$7{,}5\sqrt{\dfrac{ks}{s_b}}$
Top of second tier erection	$(5{,}0 + 0{,}02L)\sqrt{\dfrac{ks}{s_b}}$		$7{,}0\sqrt{\dfrac{ks}{s_b}}$
Top of third tier and above	$(4{,}5 + 0{,}02L)\sqrt{\dfrac{ks}{s_b}}$		$6{,}5\sqrt{\dfrac{ks}{s_b}}$
NOTE For units not subjected to wave loading, *see* 9.8.2.			

9.8.2 For erections not subjected to wave forces in any condition, the thickness of erection deck plating for all tiers need not exceed the requirements given in Table 6.9.5 for third tier erections, using:

$$s_b = 470 + 1{,}67L_2.$$

9.8.3 When decks are fitted with approved sheathing, the thickness derived from Table 6.9.5 may be reduced by 10 per cent for a 50 mm sheathing thickness, or five per cent for 25 mm, with intermediate values in proportion. The steel deck is to be coated with a suitable material in order to prevent corrosive action, and the sheathing or composition is to be effectively secured to the deck. Inside erections the thickness may be reduced by a further 10 per cent. In no case is the deck thickness to be less than 5,0 mm.

9.8.4 The thickness, t, of forecastle deck plating is to be not less than:

$$t = (6 + 0{,}017L)\sqrt{\frac{ks}{s_b}} \text{ mm.}$$

9.9 Deck stiffening

9.9.1 The requirements for deck stiffeners in this sub-Section are applicable to both beams and longitudinals.

9.9.2 Deck stiffeners on deckhouses are to have a section modulus, Z, not less than:

$$Z = 0{,}0048h_6\, s\, l_e^2\, k \text{ cm}^3\text{, but in no case less than:}$$

$$Z = 0{,}025s \text{ cm}^3$$

where the load head, h_6, is to be taken as not less than:

on first tier decks 0,9 m
on second tier 0,6 m
on third tier decks and above 0,45 m

but where the deck can be subjected to weather loading, the load, h_6, is to be increased in accordance with the requirements given in Table 6.2.1.

9.9.3 When deckhouses are subjected to specified deck loadings greater than the heads defined in 9.9.2 or are subjected to concentrated loads, equivalent load heads are to be used, *see* Table 6.2.1.

9.9.4 The section modulus of deck stiffeners on forecastles, bridges and poops is to be as required by Ch 4,4.

9.10 Deck girders and transverses

9.10.1 The scantlings of deck girders and transverses on erection decks are to be in accordance with the requirements of Table 6.4.3, using the appropriate load head, H_g, determined from Table 6.2.1.

9.11 Strengthening at ends and sides of erections

9.11.1 Web frames or equivalent strengthening are to be arranged to support the sides and ends of large erections.

9.11.2 These web frames should be spaced about 9 m apart and are to be arranged, where practicable, in line with watertight bulkheads below. Webs are also to be arranged in way of large openings, boats davits and other points of high loading.

9.11.3 Arrangements are to be made to minimise the effect of discontinuities in erections. All openings cut in the sides are to be substantially framed and have well rounded corners. Continuous coamings or girders are to be fitted below and above doors and similar openings. Erections are to be strengthened in way of davits.

9.11.4 Adequate support under the ends of erections is to be provided in the form of webs, pillars, diaphragms or bulkheads in conjunction with reinforced deck beams.

9.11.5 At the corners of deckhouses and in way of supporting structures, attention is to be given to the connection to the deck, and doublers or equivalent arrangements should generally be fitted.

9.12 Unusual designs

9.12.1 Where superstructures or deckhouses are of unusual design, the strength is to be not less than that required by this Section for a conventional design.

9.13 Aluminium erections

9.13.1 Where an aluminium alloy complying with Chapter 8 of the Rules for Materials is used in the construction of erections, the scantlings of these erections are to be increased (relative to those required for steel construction) by the percentages given in Table 6.9.6.

Table 6.9.6 Percentage increase of scantlings

Item	Percentage increase
Fronts, sides, aft ends, unsheathed deck plating	20
Decks sheathed in accordance with 9.8.3	10
Deck sheathed with wood, and on which the plating is fixed to the wood sheathing at the centre of each beam space	Nil
Stiffeners and beams	70
Scantlings of small isolated houses	Nil

9.13.2 The thickness, t, of aluminium alloy members is to be not less than:

t = 2,5 + 0,022d_w mm but need not exceed 10 mm

where

d_w = depth of the section, in mm.

9.13.3 The minimum moment of inertia, I, of aluminium alloy stiffening members is to be not less than:

$I = 5{,}25 Z\, l$ cm^4

where l is the effective length of the member l_e or l_s, in metres, as defined in 9.2 and Z is the section modulus of the stiffener and attached plating in accordance with 9.4 and 9.9, taking k as 1.

9.13.4 Where aluminium erections are arranged above a steel hull, details of the arrangements in way of the bimetallic connections are to be submitted.

9.13.5 For aluminium alloy helicopter decks, *see* Section 6.

9.14 Fire protection

9.14.1 Fire protection of aluminium alloy erections is to be in accordance with the fire safety Regulations of the appropriate National Administration, *see* Pt 7, Ch 3.

9.14.2 Where it is proposed to use aluminium alloy for items or equipment in hazardous areas, incendive sparking may constitute a risk and full details are to be submitted for consideration.

■ *Section 10*
Bulwarks and other means for the protection of crew and other personnel

10.1 General requirements

10.1.1 Bulwarks or guard rails are to be provided at the boundaries of weather decks and exposed freeboard and superstructure decks and deckhouses.

10.1.2 Bulwarks or guard rails are to be not less than 1,0 m in height measured above sheathing, and are to be constructed as required by 10.2 and 10.3. Consideration will be given to cases where this height would interfere with the normal operation of the unit.

10.1.3 The freeing arrangements in bulwarks are to be in accordance with 10.5.

10.1.4 Guard rails, as required by 10.1.1, are to consist of at least three courses and the opening below the lowest course is not to exceed 230 mm. The other courses are to be spaced not more than 380 mm apart. Where practicable, a toe plate 150 mm high is to be fitted below the lowest course. In the case of units with rounded gunwales, the guard rail supports are to be placed on the flat of the deck.

10.1.5 Satisfactory means, in the form of guard rails, lifelines, handrails, gangways, under-deck passageways or other equivalent arrangements, are to be provided for the protection of the crew in getting to and from their quarters, the machinery space and all other parts used in the necessary work of the unit. For units with production and process plant, *see also* Pt 7, Ch 3.

10.1.6 Where access openings are required in bulwarks or guard rails, they are to be fitted with suitable gates and, in general, chains are not permitted where a person could fall into the sea.

10.1.7 Where gangways on a trunk are provided by means of a stringer plate fitted outboard of the trunk side bulkheads (port and starboard), each gangway is to be a solid plate, effectively stayed and supported, with a clear walkway at least 450 mm wide, at or near the top of the coaming, with guard rails complying with 10.1.4.

10.1.8 Where a National Administration has additional requirements for the protection of the crew or personnel on board, it is the Owners' responsibility to comply with all necessary Regulations.

10.2 Construction of bulwarks

10.2.1 Plate bulwarks are to be stiffened by a strong rail section and supported by stays from the deck. The spacing of these stays forward of 0,07*L* from the forward perpendicular is to be not more than 1,2 m on surface type units and not more than 1,83 m on other unit types. Elsewhere, bulwark stays are to be not more than 1,83 m apart. Where bulwarks are cut to form a gangway or other opening, stays of increased strength are to be fitted at the ends of the openings. Bulwarks are to be adequately strengthened where required to support additional loads or attachments and in way of mooring pipes the plating is to be doubled or increased in thickness and adequately stiffened.

10.2.2 Bulwarks should not be cut for gangway or other openings near the breaks of superstructures, and are also to be arranged to ensure their freedom from main structural stresses.

10.2.3 The section modulus, Z, at the bottom of the bulwark stay is to be not less than:

$$Z = (33{,}0 + 0{,}44L)\, h^2 s \ \text{cm}^3$$

where

h = height of bulwark from the top of the deck plating to the top of the rail, in metres

s = spacing of the stays, in metres, *see* 10.2.1

L = length of unit, in metres, but to be not greater than 100 m.

10.2.4 In the calculation of the section modulus, only the material connected to the deck is to be included. The bulb or flange of the stay may be taken into account where connected to the deck, and where, at the ends of the unit, the bulwark plating is connected to the sheerstrake, a width of plating not exceeding 600 mm may also be included. The free edge of the stay is to be stiffened.

10.2.5 Bulwark stays are to be supported by, or to be in line with, suitable underdeck stiffening, which is to be connected by double continuous fillet welds in way of the bulwark stay connection.

10.2.6 When the bulwarks are required to support attachments or equipment for local operational or functional loads they are to be suitably strengthened.

10.3 Guard rail construction

10.3.1 Guard rails are, in general, to be constructed in accordance with a recognised Standard and the arrangement and spacing of guard rails are to comply with 10.1.4.

10.3.2 Stanchions are to be spaced not more than 1,5 m apart and the guard rails and their supports are to be designed to withstand a horizontal loading of 0,74 kN/m applied at the top rail. The permissible stresses in association with this loading are to be in accordance with Ch 5,2.1.1(a).

10.3.3 The stanchions and stays are to be supported by suitable under-deck stiffening.

10.3.4 When guard rails are required to support attachments for local operational or functional loads they are to be suitably strengthened.

10.4 Helicopter landing area

10.4.1 Safety nets are to be installed around the deck landing area, extending at least 1500 mm out from the perimeter. The netting is to be of approved material and of a flexible nature.

10.4.2 The safety net is to be supported at its outer edge and intermediate supports are to be spaced about 1,9 m apart. The supports are to be designed to withstand a concentrated load of 1,3 kN applied at any point on the supports. The permissible stresses are to satisfy the factors of safety given in Ch 5,2.1.1(a).

10.5 Freeing arrangements

10.5.1 In general, surface type oil storage units are to have open rails for at least half the length of the exposed part of the weather deck. Alternatively, if a continuous bulwark is fitted, the minimum freeing area is to be at least 33 per cent of the total area of the bulwark. The freeing area is to be placed in the lower part of the bulwark.

10.5.2 For self-elevating units and on surface type units, except where the additional requirements of 10.5.1 apply, the requirements of 10.5.3 to 10.5.18 are applicable.

10.5.3 Where bulwarks on the weather portions of freeboard or superstructure decks form wells, ample provision is to be made for rapidly freeing the decks of large quantities of water by means of freeing ports, and also for draining them.

10.5.4 The minimum freeing area on each side of the unit, for each well on the freeboard deck or raised quarter deck, where the sheer in the well is not less than the standard sheer required by the International Convention on Load Lines, 1966, is to be derived from the following formulae:

(a) where the length, l, of the bulwark in the well is 20 m or less: area required = 0,7 + 0,035l m^2

(b) where the length, l, exceeds 20 m: area required = 0,07l m^2

NOTE

l need not be taken greater than 0,7L_L, where L_L is the load line length of the unit in accordance with the International Convention on Load Lines, 1966.

10.5.5 If the average height of the bulwark exceeds 1,2 m or is less than 0,9 m, the freeing area is to be increased or decreased, respectively, by 0,004 m^2 per metre of length of well for each 0,1 m increase or decrease in height respectively.

10.5.6 The minimum freeing area for each well on a first tier superstructure is to be half the area calculated from 10.5.4.

10.5.7 Two-thirds of the freeing port area required is to be provided in the half of the well nearest to the lowest point of the sheer curve.

10.5.8 When the deck has little or no sheer, the freeing area is to be spread along the length of the well.

10.5.9 In units with no sheer, the freeing area as calculated from 10.5.4 is to be increased by 50 per cent. Where the sheer is less than the standard, the percentage is to be obtained by linear interpolation.

10.5.10 Where the length of the well is less than 10 m, or where a deckhouse occupies most of the length, the freeing port area will be specially considered, but in general need not exceed 10 per cent of the bulwark area.

10.5.11 Where it is not practical to provide sufficient freeing port area in the bulwark, credit can be given for bollard and fairlead openings where these extend to the deck.

10.5.12 Where a unit fitted with bulwarks has a continuous trunk or coamings, the requirements of 10.5.1 are to be complied with.

10.5.13 Where a deckhouse has a breadth less than 80 per cent of the beam of the unit, or the width of the side passageways exceeds 1,5 m, the arrangement is considered as one well. Where a deckhouse has a breadth equal to or more than 80 per cent of the beam of the unit, or the width of the side passageways does not exceed 1,5 m, or when a screen bulkhead is fitted across the full breadth of the unit, this arrangement is considered as two wells, before and abaft the deckhouse.

10.5.14 Adequate provision is to be made for freeing water from superstructures which are open at either or both ends and from all other decks within open or partially open spaces in which water may be shipped and contained.

10.5.15 Suitable provision is also to be made for the rapid freeing of water from recesses formed by superstructures, deckhouses and deck plant, etc., in which water may be shipped and trapped. Deck equipment is not to be stowed in such a manner as to obstruct unduly the flow of water to freeing ports.

10.5.16 The lower edges of freeing ports are to be as near to the deck as practicable, and should not be more than 100 mm above the deck.

10.5.17 Where freeing ports are more than 230 mm high, vertical bars spaced 230 mm apart may be accepted as an alternative to a horizontal rail to limit the height of the freeing port.

10.5.18 Where shutters are fitted, the pins or bearings are to be of a non-corrodible material, with ample clearance to prevent jamming. The hinges are to be within the upper third of the port.

10.6 Deck drainage

10.6.1 Adequate drainage arrangements by means of scuppers are to be fitted as required by Ch 7,10.

■ *Section 11*
Topside to hull structural sliding bearings

11.1 General

11.1.1 This Section covers the minimum technical requirements for the design, engineering, fabrication, assembly, inspection and testing of resilient bearing pads used as support interface between topside modules and the floating offshore installation.

11.1.2 Module bearing support arrangements are to be designed to ensure the effects of vessel deformations due to global hogging, sagging and torsion on the topside structure are minimised while moment transfer from the topside modules to the hull structure is kept to a minimum. In general this needs only to be considered for topsides modules where the support spacing is greater than three or more transverse frames.

11.2 Definitions, symbols and nomenclatures

11.2.1 For definitions, symbols and nomenclatures, *see* EN 1337 parts 1, 2, 3, 5 and 8 to 11.

11.3 References

EN 1337-1:2000, *Structural bearings – Part 1: General design rules*.
EN 1337-2:2004, *Structural bearings – Part 2: Sliding elements*.
EN 1337-2:2004, *Structural bearings – Part 3: Elastomeric bearings*.
EN 1337-8, *Structural bearings – Part 8: Guide bearings and restrain bearings*.
EN 1337: *Structural bearings – Part 5: European Standard, Construction standardisation: Pot bearing.*
EN 1337-9:1997, *Structural bearings – Part 9: Protection*.
EN 1337-10; *Structural bearings – Part 10: Inspection and maintenance*.
EN 1337-11; *Structural bearings – Part 11: Transport, storage and installation*.
Euro-code 3 – *Design of steel structures – Part 2: Steel bridge.*
BS 5400 1984: *Steel, concrete and composite bridges – Part 9: Bridge bearing.*
AASHTO/NSBA G9.1 – 2004, *Steel Bridge Bearing Design and Detailing Guidelines*.

11.4 General principle

11.4.1 **Function and types**. The bearings are located at the interface between the topside modules and the hull, their function being to minimise the structural interactions of the two bodies. Particularly, they shall reduce the bending moments in the hull module support frames as well as the tension, compression and torsion in the module primary girders. Additionally, fatigue effects will be significantly reduced on both module support frames and modules.

11.4.2 The focus of this Section is on elastomeric bearing pads which are extensively used in floating offshore installations. The bearings covered in this Section are shown in cases 1.1 to 1.8 of Table 1 of EN 1337-1.

11.5 Displacements

11.5.1 **Hull deformations and deflections**. The hull is subject to deformations and deflections resulting from:

- Longitudinal and transverse hull expansion and contraction.
- Longitudinal bending producing hogging and/or sagging.
- Axial torsion.

Hull hogging and sagging result in relative movement between the topside module, at the support nodes, and the module support frames. These relative movements may be caused by a combination of the following factors:

- Temperature variation between hull construction and hull operational conditions.
- Waves/environmental conditions.
- Variations to the distribution of topside and cargo loads along the vessel.

11.5.2 **The effect of displacement on bearings**. Horizontal displacements will induce rubber strain in elastomeric bearings, and will induce sliding upon PTFE/steel surfaces for pot bearings, while vertical displacements will induce compression or tension in both types. These effects must be considered in line with the bearing material's shear, tension and compression properties.

11.5.3 **Rotations for bearing design**. In the absence of detailed analysis, the bearings are to be designed for a minimum rotation of +/–0,5 degrees about both horizontal axes to ensure topside members satisfy the allowable deflection criterion of 1:300.

NOTE
The rotation is a minimum criterion as opposed to maximum as previously proposed.

11.6 Serviceability, maintenance and protection requirements

11.6.1 Bearings under topside structures may be exposed to dirt, debris, oil and moisture that promote corrosion and deterioration. As a result, these bearings should be designed and installed to minimise environmental damage and to allow easy access for inspection. The service demands on bearings are very severe and result in a service life that is typically shorter than that of other structural elements. Therefore, allowance for bearing replacement should be given consideration in the design process and, where possible, lifting locations should be provided to facilitate removal and re-installation of bearings without damaging the structure. *See* EN 1337-9, 10 and 11 for specifications.

11.7 Additional requirements

11.7.1 **Design life**. The module bearings are required to be designed for the same service life as the module structures. The supplier of bearing material is to provide adequate evidence to support the design life of the bearings under the specified project's conditions.

11.7.2 **Environmental conditions**. The module bearings shall withstand the following environmental conditions:

- Air temperature.
- Humidity.
- Solar radiation.
- Flare radiation.
- Hydrocarbon/cryogenic spills.
- Salt-water spray.

The bearings could come into contact with miscellaneous hydrocarbons due to leakages occurring on the process equipments located on the modules. The supplier shall consider this potential event and ensure the proposed solution and supplied products do not jeopardise structural integrity or satisfactory system performance over the design life, in the event that this potential condition occurs.
However, bearing pads are not designed for blast, fire or cryogenic spills events. If necessary, a protection of bearing pads will be designed to ensure their integrity.
Passive fire protection of the bearings may be considered to protect pads against fire events.

11.7.3 Modules are to be constrained against excessive movement with lateral restraints, for example, horizontal stoppers for sliding bearings. Modules are also to be constrained against uplift unless it can be confirmed that uplift cannot occur. Consideration should be given to restricting the number of longitudinal supports to two to prevent transfer of vertical displacement of the hull to the module.

11.8 Bearing selection

11.8.1 Bearing selection is influenced by many factors, including loads, geometry, maintenance, available clearance, displacement, rotation, deflection, availability, policy, designer preference, construction tolerances and cost. In general, vertical displacements are restrained, rotations are allowed to occur as freely as possible, *see* 11.5.3, and horizontal displacements may be either accommodated or restrained. The reaction loads on each bearing are to be in accordance with the topside structural analysis and are to account for the worst scenario loading condition, taking the relative stiffness between the topsides and hull structure into account in the analysis, as appropriate.

11.8.2 Typically, steel stoppers are used with elastomeric bearings to transfer horizontal forces from topside to the substructure. The load transfer system between bearing plates and stoppers shall be carefully designed in order to minimise impact effects.

11.9 Elastomer

11.9.1 The shear stiffness of the bearing is its most important property because it affects the forces transmitted between the superstructure and substructure. Elastomers are flexible under shear and uniaxial deformation, but they are very stiff against volume changes. This feature makes possible the design of a bearing that is flexible in shear but stiff in compression.

11.9.2 Only neoprene for plain elastomeric bearing pads and steel-reinforced elastomeric bearings is recommended. All elastomers are visco-elastic, non-linear materials and, therefore, their properties vary with strain level, rate of loading and temperature. Bearing manufacturers evaluate the materials on the basis of international rubber hardness degrees (IRHD). However, this parameter is not considered to be a good indicator of the shear modulus '*G*'. The shear modulus '*G*' should not be taken less than 0,7 MPa (an IRHD not less than 50 or 55).

11.10 Fatigue

11.10.1 EN 1337 provides only test and design methods for repeated compression loadings. These should be followed in detail.

11.11 Detailing

11.11.1 Care should be taken for design of load transfer in fixed and sliding bearings. Sliding bearings should be designed according to EN1337-2. Maximum deflections under each loading case should be calculated considering non-linear behaviour. No gaps between bearing plates and stoppers are allowed. For common details, *see Steel Bridge Bearing Design and Detailing Guidelines*, AASHTO/NSBA G9.1 – 2004.

Watertight and Weathertight Integrity and Load Lines

Section

■ *Section 1* General

1.1 Application

1.1.1 This Chapter gives the minimum classification requirements for watertight and weathertight integrity and load line application.

1.1.2 The requirements for intact and damage stability and the assignment of load lines are to be in accordance with Pt 1, Ch 2,1.

1.1.3 The requirements in this Chapter may be modified where necessary to take into account the requirements of the appropriate National Administration responsible for the intact and damage stability of the unit.

1.1.4 For the purpose of this Chapter, the basic types of units are those defined in the International Convention on Load Lines, 1966, *see also* Pt 3 Ch 11,1.1 of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships).

1.2 Plans to be submitted

1.2.1 The following plans are to be submitted for approval:

- Deck drainage, scuppers and sanitary discharges.
- Ventilators and air pipes (including closing appliances).
- Watertight doors and hatch covers (internal and external) showing scantlings, coamings and closing appliances.
- Weathertight doors and hatch covers showing scantlings, coamings and closing appliances.
- Windows and side scuttles.
- Schematic diagrams of local and remote control of watertight and weathertight doors and hatch covers and other closing appliances.
- Location of control rooms.
- Freeing arrangements.

1.2.2 The following plans are to be submitted for information:

- General arrangement.
- Arrangement plan indicating the defined watertight boundaries of spaces included in the buoyancy.
- Arrangement plans of watertight doors and hatches.
- Details of intact and worst damage stability waterlines shown in elevations and plan views.
- Freeboard plan showing the maximum design operating draughts in accordance with Load Line Regulations and indicating the position of all external openings and their closing appliances.
- Location of down flooding openings.
- Trim and stability booklet, *see* Pt 1, Ch 2.

■ *Section 2* Definitions

2.1 Freeboard deck

2.1.1 The freeboard deck is normally the uppermost complete deck exposed to weather and sea, which has permanent means of closing all openings in the weather part, and below which all openings in the sides of the unit are fitted with permanent means of watertight closing. For semi-submersible units, *see also* 5.2.4.

2.2 Freeboard

2.2.1 Freeboard is the distance measured vertically downwards amidships from the upper edge of the deck line to the upper edge of the related load line.

2.3 Weathertight

2.3.1 A closing appliance is considered weathertight if it is designed to prevent the passage of water into the unit in any sea conditions.

2.3.2 Generally, all openings in the freeboard deck and in enclosed superstructures are to be provided with weathertight closing appliances.

2.4 Watertight

2.4.1 A closing appliance is considered watertight if it is designed to prevent the passage of water in either direction under a head of water for which the surrounding structure is designed.

2.4.2 Generally, all openings below the freeboard deck in the outer shell boundaries and in main watertight decks and bulkheads are to be fitted with permanent means of watertight closing.

2.4.3 When the Rules require closing appliances with closely bolted covers, the pitch of the securing bolts is not to exceed five diameters.

2.5 Position 1 and Position 2

2.5.1 For the purpose of Load Line conditions of assignment, there are two basic positions of hatchways, doorways and ventilators defined as follows:

Position 1 – Upon exposed freeboard and raised quaterdecks, and exposed superstructure decks within the forward $0,25L_L$.

Position 2 – Upon exposed superstructure decks abaft the forward $0,25L_L$.

where

L_L = the load line length in accordance with the *International Convention on Load Lines, 1966*.

2.5.2 The application to column-stabilised units will be specially considered, *see* 5.2.4.

2.6 Damage waterline

2.6.1 The damage waterline is the final equilibrium waterline after damage defined in the applicable stability Regulations, *see* 1.1.2.

2.7 Intact stability waterline

2.7.1 The intact stability waterline is the most severe inclined waterline to satisfy the range of intact stability defined in the applicable stability Regulations, *see* 1.1.2.

2.8 Down flooding

2.8.1 Down flooding means any flooding of the interior of any part of the buoyant structure of a unit through openings which cannot be closed watertight or weathertight, as appropriate, in order to meet the intact or damage stability criteria or which are required for operational reasons to be left open.

2.8.2 The down flooding angle is the least angle of heel at which openings in the hull, superstructure or deckhouses, which cannot be closed weathertight, immerse and allow flooding to occur.

2.8.3 Intact stability is to comply with Pt 1, Ch 2,1.

■ *Section 3* Installation layout and stability

3.1 Control rooms

3.1.1 Control rooms essential for the safe operation of the unit in an emergency are to be situated above zones of immersion after damage, as high as possible and as near a central position on the unit as is practicable. The requirements for the central ballast control station on column-stabilised units are to be in accordance with Pt 6, Ch 1,2.8.

3.2 Damage zones

3.2.1 The extent of defined damage is to be in accordance with the applicable damage stability Regulations.

3.2.2 All piping, ventilation ducts and trunks, etc., should, where practicable, be situated clear of the defined damage zones. When piping, ventilation ducts and trunks, etc., are situated within the defined extent of damage, they are to be assumed damaged and positive means of closure are to be provided at watertight subdivisions to preclude progressive flooding of other intact spaces, *see also* Pt 5, Ch 13,2.

3.2.3 In addition to the defined damages referred to in 3.2.1, compartments with a boundary formed by the bottom shell of the unit are to be considered flooded individually unless agreed otherwise with LR.

■ *Section 4* Watertight integrity

4.1 Watertight boundaries

4.1.1 All units are to be provided with watertight bulkheads, decks and flats to give adequate strength and the arrangements are to suit the requirements for subdivision, floodability and damage stability. In all cases, the plans submitted are to clearly indicate the location and extent of the bulkheads. In the case of column-stabilised drilling units, the scantling of the watertight flats and bulkheads are to be made effective to that point necessary to meet the requirements of damage stability and are to be indicated on the appropriate plans.

4.1.2 The number and disposition of watertight bulkheads are to comply with Ch 3,5.

4.1.3 The strength of watertight subdivisions are to comply with Ch 6,7.

4.1.4 Surface type units are to be fitted with a collision bulkhead in accordance with Pt 3, Ch 3,4.2 of the Rules for Ships.

4.2 Tank boundaries

4.2.1 Deep tanks for fresh water, fuel oil or any other tanks which are not normally kept filled in service are, in general, to have wash bulkheads or divisions.

4.2.2 Tank bulkheads and watertight divisions are to have adequate strength for the maximum design pressure head in normal operating and damage conditions and the scantlings are to comply with Ch 6,7.

4.3 Boundary penetrations

4.3.1 Where internal boundaries are required to be watertight to meet damage stability requirements, the number of openings in such boundaries is to be reduced to the minimum compatible with the design and proper working of the unit.

4.3.2 Where piping, including air and overflow pipes, ventilation ducts, shafting, electric cable runs, etc., penetrate watertight boundaries, arrangements are to be made to ensure the watertight integrity of the boundary. Details of the arrangements are to be submitted for approval.

4.3.3 No openings such as manholes, watertight doors, pipelines or other penetrations are to be cut in the collision bulkhead of surface type units, except as permitted by Pt 5, Ch 13,3 and 4.

4.3.4 Where pipelines or ducts serve more than one compartment, satisfactory arrangements are to be provided to preclude the possibility of progressive flooding through the system to other spaces in the event of damage, *see also* 3.2.

4.3.5 Where piping systems and ventilation ducts are designed to watertight standards and are suitable for the maximum design pressure head in damage conditions, they are to be provided with valves at the boundaries of each watertight compartment served.

4.3.6 Ventilation ducts which are of non-watertight construction are to be provided with valves where they penetrate watertight subdivision boundaries.

4.3.7 Where valves are provided at watertight boundaries to maintain watertight integrity in accordance with 4.3.5 and 4.3.6, these valves are to be capable of being operated from a pump-room or other normally manned space, a weather deck, or a deck which is above the final waterline after flooding. In the case of a column-stabilised unit, this would be the central ballast control station. Valve position indicators should be provided at the remote control station, weather deck or a normally manned space.

4.3.8 For self-elevating units, the ventilation system valves required to maintain watertight integrity should be kept closed when the unit is afloat. Necessary ventilation in this case should be arranged by alternative approved methods.

4.4 Internal openings related to damage stability

4.4.1 The requirements for the operation, alarm displays and controls of watertight doors and hatch covers and other closing appliances are given in Pt 7, Ch 1,9.

4.4.2 Internal access openings fitted with appliances to ensure watertight integrity, are to comply with the following:

(a) Watertight doors and hatch covers which are used during the operation of the unit while afloat may normally be open, provided the closing appliances are capable of being remotely controlled from a damage central control room on a deck which is above any final waterline after flooding and are also to be operable locally from each side of the bulkhead. Open/shut indicators are to be provided in the control room showing whether the doors are open or closed. In addition, remotely operated doors provided to ensure the watertight integrity of internal openings which are used while at sea are to be sliding watertight doors with audible alarm. The power, control and indicators are to be operable in the event of main power failure. Particular attention is to be paid to minimising the effect of control system failure. Each power-operated sliding watertight door is to be provided with an individual hand-operated mechanism. It shall be possible to open/close the door by hand at the door itself from both sides.

(b) Doors or hatch covers in self-elevating units or doors placed above the deepest load line draft in column-stabilised and surface units, which are normally closed while the unit is afloat may be of the quick acting type and should be provided with an alarm system (e.g., light signals) showing personnel both locally and at the central ballast control station whether the doors or hatch covers in question are open or closed. A notice should be affixed to each such door or hatch cover stating that it is not to be left open while the unit is afloat.

(c) The closing appliances are to have strength, packing and means for securing which are sufficient to maintain watertightness under the maximum design water pressure head of the watertight boundary under consideration.

4.4.3 Internal openings fitted with appliances to ensure watertight integrity, which are to be kept permanently closed while afloat, are to comply with the following:

(a) A notice to the effect that the opening is always to be kept closed while afloat is to be attached to the closing appliances in question.

(b) Opening and closing of such closing appliances are to be noted in the unit's logbook, or equivalent.

(c) Manholes fitted with gaskets and closely bolted covers need not be dealt with as under (a).

(d) The closing appliances are to have strength, packing and means for securing which are sufficient to maintain watertightness under the maximum water pressure head of the watertight boundary under consideration.

4.5 External openings related to damage stability

4.5.1 Where watertight integrity is dependent on external openings which are used during the operation of the unit while afloat, they are to comply with the following:

(a) The lower edge of openings of air pipes (regardless of their closing appliances) is to be above the final equilibrium damage waterline including wind heel effects.
(b) The lower edge of ventilator openings, doors and hatches with manually operated means of weathertight closures is to be above the final equilibrium damage waterline including wind heel effects.
(c) Openings such as manholes, fitted with gaskets and closely bolted covers, and side scuttles and windows of the non-opening type with inside hinged deadlights which are fitted with appliances to ensure watertight integrity, may be submerged. Such openings are not allowed to be fitted in the column of stabilised units.
(d) Scuppers and discharges are to be fitted with closing appliances, *see* 10.1.
(e) Where flooding of chain lockers or other buoyant volumes may occur, the openings to these spaces should be considered as downflooding points.

4.5.2 Where watertight integrity is dependent upon external openings which are permanently closed during the operation of the unit while afloat, such openings are to comply with the requirements of 4.4.3.

4.5.3 External watertight doors and hatch covers of limited size which are used while afloat may be accepted below the worst damage waterline, including wind heel effects, provided they are on or above the freeboard deck and the closing appliances comply with the requirements of 4.4.2(a) and (b).

4.6 Strength of watertight doors and hatch covers

4.6.1 The symbols used in this sub-Section are as follows:

d = distance between securing devices, in metres

f_1 = $1{,}1 - \dfrac{s}{2500 l_s}$ but not greater than 1

h_D = design pressure head, in metres, measured vertically from the bottom of the door to the worst damage waterline plus 5 m

k = higher tensile steel factor as defined in Ch 2,1.2

l_s = span of stiffener between support points, in metres

s = spacing of stiffeners, in mm

P_I = packing line pressure along edges, in N/cm (kgf/cm), but not less than 50 (5,1).

4.6.2 Closing appliances for internal and external openings are to have scantlings in accordance with this sub-Section and are to satisfy the requirements of 4.4 and 4.5 respectively.

4.6.3 In general, watertight closing appliances are to be designed to withstand the design pressure head from both sides of the appliance unless the mode of failure based on the damage stability criteria can only result in one-sided pressure loading.

4.6.4 The thickness of plating, t, subjected to lateral pressure in damage conditions is to be not less than:

$t = 0{,}0048 s\, f_1 \sqrt{h_D k}$ mm but not less than 8 mm.

4.6.5 The section modulus, z, of panel stiffeners fitted in one direction and edge stiffeners is not to be less than:

$z = 0{,}0065 s\, k\, h_D\, l_s^2$ cm^3 but not less than 15 cm^3

The section modulus of secondary panel stiffeners may also be determined from the above formula, but doors with stiffeners designed as grillages will be specially considered.

4.6.6 The moment of inertia, I, of edge stiffeners is in general not to be less than:

$I = 0{,}8 P_I d^4$ cm^4 ($8 P_I d^4$ cm^4)

4.6.7 Securing devices for closing appliances are to be designed for water pressure acting on the opposite side of the appliance to which they are positioned, *see also* 4.6.3.

4.6.8 The strength of the bulkhead and deck framing in way of watertight closing appliances is to comply with the requirements of Ch 6,7.

4.6.9 Watertight closing appliances are to be hydraulically tested in accordance with the requirements of Table 1.8.1 in Pt 3, Ch 1,8 of the Rules for Ships. In general, the test is to be carried out before the appliance is fitted to the unit. The test pressure is to be applied separately to both sides of the appliance, *see also* 4.6.3.

4.6.10 After installation in the unit, watertight closing appliances are to be hose tested in accordance with the requirements of Table 1.8.1 in Pt 3, Ch 1,8 of the Rules for Ships, and functional tests are to be carried out to verify the satisfactory operation of the appliance, its control and alarm functions, as required by Pt 7, Ch 1,9.

4.7 Weathertight integrity related to stability

4.7.1 Any opening, such as an air pipe, ventilator, ventilation intake or outlet, non-watertight sidescuttle, small hatch, door, etc., having its lower edge submerged below a waterline associated with the zones indicated in (a) or (b), is to be fitted with a weathertight closing appliance to ensure the weathertight integrity, when:

(a) A unit is inclined to the range between the first intercept of the right moment curve and the wind heeling moment curve and the angle necessary to comply with the requirements of 3.3 of the 2009 IMO MODU Code during the intact condition of the unit while afloat; and
(b) A column-stabilised unit is inclined to the range:
    (i) Necessary to comply with the requirements of 4.7.1(a) and 5.2.6 and with a zone measured 4,0 m perpendicularly above the final damaged waterline per 3.4.3 of the 2009 IMO MODU Code referred to Fig. 7.4.1, and

(ii) Necessary to comply with the requirements of 3.4.4 of the 2009 IMO MODU Code.

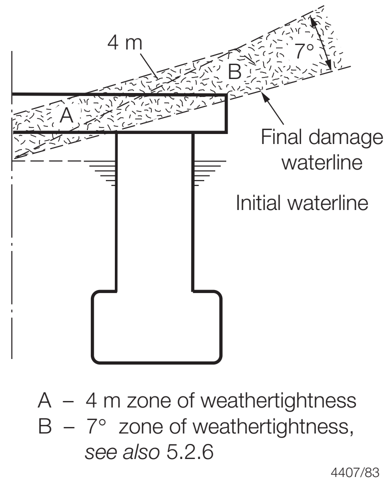


Fig. 7.4.1
Minimum weathertight integrity requirements for column-stabilised units

4.7.2 External openings fitted with appliances to ensure weathertight integrity, which are kept permanently closed while afloat, are to comply with the requirements of 4.4.3(i) and (ii).

4.7.3 External openings fitted with appliances to ensure weathertight integrity, which are secured while afloat are to comply with the requirements of 4.4.2(i) and (ii).

■ *Section 5*
Load lines

5.1 General

5.1.1 Any unit to which a load line is required to be assigned under the applicable terms of the Load Line Convention is to be subject to compliance with the Convention, *see* 1.1.2. For semi-submersible and self-elevating units, *see also* 5.2 and 5.3 respectively.

5.1.2 The requirements of the Load Line Convention, with respect to weathertightness and watertightness of decks, superstructures, deckhouses, doors, hatchway covers, other openings, ventilators, air pipes, scuppers, inlets and discharges, etc., are taken as a basis for all units in the afloat conditions.

5.1.3 The requirements for hatchways, doors and ventilators are dependent upon the position on the unit as defined in 2.5.

5.1.4 Units which cannot have freeboard computed by normal methods laid down by the Load Line Convention will have the permissible draughts determined on the basis of meeting the applicable intact stability, damage stability and structural requirements for transit and operating conditions while afloat. In no case is the draught to exceed that permitted by the Load Line Convention, where applicable.

5.1.5 All units are to have load line marks which designate the maximum permissible draught when the unit is in the afloat condition. Such markings are to be placed at suitable visible locations on the structure, to the satisfaction of LR. These marks, where practicable, are to be visible to the person in charge of mooring, lowering or otherwise operating the unit.

5.2 Column-stabilised units

5.2.1 Load lines for column-stabilised units are to be based on the following:

- The strength of the structure.
- The air gap between the maximum operating waterline and the bottom of the upper hull structure.
- The intact and damage stability requirements.

5.2.2 The conditions of assignment are to be based on the requirements of the Load Line Convention. The Regulations of the relevant National Administration are also to be complied with, *see* 1.1.2.

5.2.3 In general, the heights of hatch and ventilator coamings, air pipes, door sills, etc., in exposed positions and all closing appliances are to be determined by consideration of both intact and damage stability requirements.

5.2.4 The freeboard deck and reference deck from which the air gap is measured, is normally taken as the lowest continuous deck exposed to weather and sea, and which has permanent means of closing and below which all openings are watertight and permanently closed at sea.

5.2.5 Side scuttles and windows, including those of non-opening type, or other similar openings, are not to be fitted below the freeboard deck, as defined in 5.2.4.

5.2.6 In addition to the stability requirements in 4.7, the upper deck and the boundaries of the enclosed upper hull structure between the upper deck and the freeboard deck are to be made weathertight.

5.2.7 Special consideration will be given to the position of openings which cannot be closed in emergencies, such as air intakes for emergency generators.

5.3 Self-elevating units

5.3.1 Load lines and conditions of assignment for self-elevating units when afloat in transit conditions will be subject to the applicable terms of the Load Line Convention. A load line, where assigned, is not applicable to self-elevating units when resting on the sea bed, or when lowering to or raising from such position. The Regulations of the relevant National Administration are also to be complied with, *see* 1.1.2.

5.3.2 Special consideration is to be given to the freeboard of units with moonpools or drilling wells extending through the main hull structure.

5.3.3 In general, the heights of hatch and ventilator coamings, air pipes, door sills, etc., in exposed positions and all closing appliances are also to be determined by consideration of both intact and damage stability requirements.

5.4 Surface type units

5.4.1 Surface type units are to comply with the requirements of 5.1.1. Special consideration is to be given to the freeboard of units with moonpools or drilling wells extending through the main hull structure.

5.5 Sea bed-stabilised units

5.5.1 When afloat in transit conditions, sea bed-stabilised units are to comply with the requirements of 5.2 and 5.3 as applicable.

5.6 Weathertight integrity

5.6.1 Closing arrangements for shell, deck and bulkhead openings and the requirements for ventilators, air pipes and overboard discharges, etc., are to comply with Sections 6 to 10.

5.6.2 The requirements of this Chapter conform, where relevant, with those of the Load Line Convention. Reference should also be made to any additional requirements of the National Authority of the country in which the unit is to be registered and to the appropriate Regulations of the Coastal State Authority in the area where the unit is to operate.

5.6.3 The closing appliances are, in general, to have a strength at least corresponding to the required strength of that part of the hull in which they are fitted.

5.6.4 The requirements for closing appliances of hatches, doors, ventilators, air pipes, etc., and their associated coamings, situated at such a height as will not constitute a danger to the weathertightness of the unit, will be specially considered.

5.6.5 In all areas where mechanical damage is likely, all air and sounding pipes, scuppers and discharges, including their valves, controls and indicators, are to be well protected. This protection is to be of steel or other equivalent material.

■ *Section 6* Miscellaneous openings

6.1 Small hatchways on exposed decks

6.1.1 The requirements of Pt 3, Ch 11,6.1 of the Rules for Ships are to be complied with, as applicable.

6.1.2 In general, small hatch cover scantlings and securing devices are to be in accordance with Table 7.6.1 or with an acceptable standard.

Table 7.6.1 Hatch cover scantlings

Size of hatch (mm)	Plate (mm)	Stiffeners	Toggles
600 x 600	8,0	–	4
760 x 760	8,0	–	6
925 x 925	8,0	75 x 7,5 mm flat bar	7
1220 x 1220	10,0	75 x 7,5 mm flat bar	8

6.1.3 Hatch covers of a greater size than those defined in Table 7.6.1 will have their scantlings and closing arrangements specially considered.

6.1.4 When applicable, large hatch covers are to comply with the requirements of Pt 3, Ch 11 of the Rules for Ships.

6.1.5 Small hatches, including escape hatches, are to be situated clear of any obstructions.

6.1.6 The height and scantlings of coamings are to be in accordance with 6.3.

6.2 Hatchways within enclosed superstructures or ‘tween decks

6.2.1 The requirements of 6.1 are to be complied with, where applicable.

6.2.2 Access hatches within a superstructure or deckhouse in Position 1 or 2 need not be provided with means for closing if all openings in the surrounding bulkheads have weathertight closing appliances.

6.3 Hatch coamings

6.3.1 The height of coamings of hatchways situated in Positions 1 and 2 closed by steel covers fitted with gaskets and clamping devices are to be not less than:

- 600 mm at Position 1;
- 450 mm at Position 2.

6.3.2 Lower heights than those defined in 6.3.1 may be considered in relation to operational requirements and the nature of the spaces to which access is given.

6.3.3 Coamings with height less than given in 6.3.1 may normally be accepted for column-stabilised units after special consideration, *see also* 6.3.4.

6.3.4 Coaming heights on all units are also to satisfy the requirements for intact and damage stability, *see* 4.5 and 4.7.

6.3.5 The thickness of the coamings is to be not less than the minimum thickness of the structures to which they are attached, or 11 mm, whichever is the lesser. Stiffening of the coaming is to be appropriate to its length and height. Scantlings of coamings more than 900 mm in height will be specially considered.

6.4 Manholes and flush scuttles

6.4.1 Manholes and flush scuttles fitted in Positions 1 and 2, or within superstructures other than enclosed superstructures, are to be closed by substantial covers capable of being made watertight. Unless secured by closely spaced bolts, the covers are to be permanently attached.

6.5 Companionways, doors and access arrangements on weather decks

6.5.1 The requirements of Pt 3, Ch 11,6.4 of the Rules for Ships are to be complied with, as applicable.

6.5.2 For access to spaces in the oil storage area on units with tanks for the storage of oil in bulk, *see* Pt 3, Ch 3,2.11.

6.5.3 The height of doorway sills above deck sheathing, if fitted, is to be not less than 600 mm in Position 1, and not less than 380 mm in Position 2. For semi-submersible units, *see* 5.2.3.

6.5.4 Doorway sill heights on all units are also to satisfy the requirements for intact and damage stability, *see* 4.5 and 4.7.

6.5.5 On surface type oil storage units, direct access from the freeboard deck to the machinery space through exposed casings is not permitted, except when 6.5.6 applies. A door complying with 6.5.3 may, however, be fitted in an exposed machinery casing on these units, provided that it leads to a space or passageway which is of equivalent strength to the casing and is separated from the machinery space by a second weathertight door complying with 6.5.3. The outer and inner weathertight doors are to have sill heights of not less than 600 mm and 230 mm respectively and the space between is to be adequately drained by means of a screw plug or equivalent.

6.5.6 For surface type oil storage units with freeboards greater than, or equal to, a Type B ship (as defined in the Load Line Convention), inner doors are not required for direct access to the engine room.

6.6 Side scuttles, windows and skylights

6.6.1 For surface type and self-elevating units, when afloat, the requirements of Pt 3, Ch 11,6.5 of the Rules for Ships are to be complied with, as applicable.

6.6.2 A plan showing the location of side scuttles and windows is to be submitted. Attention is to be given to any relevant Statutory Requirements of the Coastal State Authority where the unit is to operate and/or the National Authority of the country in which the unit is to be registered.

6.6.3 The location of windows and side scuttles and the provision of deadlights or storm covers on semi-submersible units will be specially considered in each case, *see also* 4.5.1(c) and 5.2.5.

6.6.4 Windows and side scuttles are to be of the non-opening type where damage stability calculations indicate that they would become immersed as a result of specified damage.

■ *Section 7* Tank access arrangements and closing appliances in oil storage units

7.1 General

7.1.1 The requirements of Pt 3, Ch 11,7 of the Rules for Ships are to be complied with, as applicable.

7.1.2 The height of coamings may be required to be increased if this is shown to be necessary by damage stability regulations.

7.1.3 Access openings are to have smooth edges and edge stiffening is also to be arranged in regions of high stress.

7.1.4 Small openings are to be kept clear of other access openings.

7.1.5 The general requirements for access to spaces within the oil storage area are to comply with Pt 3, Ch 3,2.11.

■ *Section 8* Ventilators

8.1 General

8.1.1 The requirements of Pt 3, Ch 12,2 of the Rules for Ships are to be complied with, as applicable.

8.1.2 Ventilators from deep tanks and tunnels passing through pontoons, columns and 'tween decks are to have scantlings suitable for withstanding the pressures to which they may be subjected, and are to be made watertight.

8.1.3 Ventilator coaming heights and closing appliances on all units are also to satisfy the requirements for intact and damage stability, *see* 4.5 and 4.7.

8.1.4 On self-elevating units, it is recommended that closing appliances for ventilators situated on the freeboard deck are fitted at or below the deck level.

8.1.5 Mushroom ventilators closed by a head revolving on a centre spindle (screw-down head) are acceptable in Position 2, and also in sheltered positions in Position 1, but the diameter is not to exceed 300 mm on self-elevating units. On self-elevating units, a notice indicating 'keep closed while unit is afloat' is to be attached to the head.

8.1.6 A ventilator head not forming part of the closing arrangements is to be not less than 5,0 mm thick on column-stabilised units and 6,5 mm thick on other units.

8.1.7 Wall ventilators (jalousies) may be accepted, provided they are capable of being closed weathertight by hinged steel gasketed covers secured by bolts or toggles, or equivalent arrangements provided.

8.1.8 Fire dampers are not acceptable as ventilator closing appliances unless they are of substantial construction, gasketed, and able to be secured weathertight in the closed position.

8.1.9 Reference should be made to 8.1.3 concerning down flooding through ventilators which do not require closing appliances due to their coaming height being in accordance with Pt 3, Ch 12,2.3.1 of the Rules for Ships.

■ *Section 9*
Air and sounding pipes

9.1 General

9.1.1 The requirements of Pt 3, Ch 12,3 of the Rules for Ships and Pt 5, Ch 13,12 are to be complied with, as applicable.

9.1.2 Air pipes are generally to be led to an exposed deck and are to be well protected from mechanical damage.

9.1.3 Air pipes are also to satisfy the requirements for intact and damage stability, *see* 4.5 and 4.7.

9.1.4 All openings of air and sounding pipes are to be provided with approved automatic type closing appliances which prevent the free entry of water and excessive pressure imposed on the tank.

9.1.5 Pressure/vacuum valves as required by Pt 5, Ch 15 may be accepted as closing appliances for oil storage tanks.

■ *Section 10*
Scuppers and sanitary discharges

10.1 General

10.1.1 The requirements of Pt 3, Ch 12,4 of the Rules for Ships are to be complied with, as applicable.

10.1.2 The additional requirements contained within this Section are applicable to semi-submersible and self-elevating units only.

10.1.3 Normally, each separate overboard discharge from an enclosed space is to be fitted with an automatic non-return valve at the shell boundary. Where the inboard end of a discharge is situated below the worst damage water line, the non-return valve is to be of a type which is effective at the worst expected inclination after damage, whatever the orientation, and is to have a positive means of closing, operable from a readily accessible position above the damage water line. An indicator is to be fitted at the control position showing whether the valve is open or closed.

10.1.4 The requirements for non-return valves are applicable only to those discharges which remain open while the unit is afloat during normal operation. For discharges which are closed while the unit is afloat, such as gravity drains from tanks, a single screw-down valve operated from the freeboard deck is considered to provide sufficient protection. An indicator is to be fitted at the control position showing whether the valve is open or closed.

10.1.5 The non-return valve required by 10.1.3 is to be mounted directly on the shell and secured in accordance with Pt 5, Ch 13,2.4. If this is impracticable, a short distance piece of rigid construction may be introduced between the valve and the shell.

10.1.6 Discharge piping, situated between the sea level and the bottom of the upper hull of semi-submersible units and below the bottom shell of the self-elevating units when in the elevated position, is to be of substantial construction, well secured and protected.

Section 1 General

1.1 Application

1.1.1 This Chapter is applicable to all unit types and components.

1.1.2 Requirements are given in this Chapter for the following:

(a) Welding connection details, defined practices and sequence, consumables and equipment, procedures, workmanship and inspection.
(b) End connection scantlings and constructional details for longitudinals, beams, frames and bulkhead stiffeners.
(c) Primary member proportions, stiffening and construction details.

1.1.3 All units are to comply with the requirements of Pt 3, Ch 10 of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships), as applicable to the type of unit. Additional requirements as indicated in the following Sections should also be complied with, as applicable.

1.2 Symbols

1.2.1 Symbols are defined as necessary in each Section.

Section 2 Welding

2.1 General

2.1.1 Requirements for welding are given in Chapter 12 and Chapter 13 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials) and general requirements for hull construction are also given in Pt 3, Ch 10,2 of the Rules for Ships.

2.1.2 Additional requirements with respect to unit types as indicated in this Section should also be complied with, as applicable.

2.2 Impact test requirements

2.2.1 Charpy V-notch impact tests are to be carried out in the weld metal, fusion line and heat affected zone in accordance with 2.2.2 to 2.2.4.

2.2.2 For special structure, the impact test temperature and minimum absorbed energy for the weld and heat affected zone are to be the same as that specified for the base materials being welded.

2.2.3 For primary and secondary structure, the impact test temperature and the minimum absorbed energy for the weld metal and heat affected zone are to be in accordance with the requirements of the material grade being welded, as specified in Table 12.2.2 in Chapter 12 of the Rules for Materials.

2.2.4 Fabrications whose thickness exceeds 65 mm are, in general, to be subjected to a post weld heat treatment. Impact tests are required to be made on specimens heat treated in the same manner as the actual construction. The absorbed energy is to be in accordance with 2.2.2 and 2.2.3; however, the test temperatures may be 10°C higher.

2.3 Workmanship and inspection

2.3.1 Checkpoints examined at the construction stage are generally to be selected from those welds intended to be examined as part of the agreed quality control programme to be applied by the Builder. The locations and numbers of checkpoints are to be agreed between the Builder and the Surveyor. Special attention is to be paid to the welded connections of primary bracings and their end connections and other structure defined as special in Ch 2,2.

2.3.2 Additional locations for NDE for surface type units are shown in Table 8.2.1.

2.3.3 Typical locations for NDE and the recommended number of checkpoints to be taken in column-stabilised and self-elevating units are shown in Table 8.2.2. For other unit types, the extent of NDE will be specially considered in each case. Critical locations as identified by LR's *ShipRight Fatigue Design Assessment* and other relevant fatigue calculations are also to be considered, where applicable. A document detailing the proposed items to be examined is to be submitted by the Builder for approval.

2.3.4 For the hull structure of units designed to operate in low air/sea temperatures, the recommended extent of non-destructive examination will be specially considered.

2.3.5 All NDE is to be performed in accordance with the requirements specified in Ch 13,2 of the Rules for Materials.

2.3.6 In general, fabrication tolerances are to comply with Section 6. It is important to ensure that compatibility exists between design calculations and construction standards, particularly in fatigue sensitive areas.

Table 8.2.1 Additional non-destructive examination of welds on surface type units (as applicable)

Recommended extent of testing, *see* Note 1 General, *see* Notes 8 and 9		
Structural item	Location	Checkpoints, *see* Note 1
Penetrations and attachments to hull, e.g., sea inlets, piping, anode supports	Throughout	100%
Moonpool integration structure	Throughout	*See* Notes 2 and 4
Topside support structure connections to hull and hull structure in way	Throughout	25%, *see* Notes 4 and 5
Flare stack and crane pedestal structure	Throughout	50%, *see* Notes 4 and 5
Connections to deck	Local	100%
Other structural items	Throughout	*See* Notes 3 and 4
Side shell butts, seams and intersection welds where vessel is strengthened for operations in ice	Forward end Remainder	*See* Note 6 *See* Note 7
Exposed shell butts, seams and intersection welds where vessel is designed for low temperature operations	Throughout	*See* Note 7
Local areas identified as fatigue sensitive, e.g.: • Identified bracket connections at intersections of side shell longitudinals and transverse frames and bulkheads • Key locations identified on moonpool integration structure • Topside support stool welds to upper deck and underdeck welds in way • Flare stack support welds to upper deck and underdeck welds in way	 Local Local Local Local	 *See* Note 3 100% 100% 100%
Other items	Local	*See* Notes 3 and 4

NOTES
1. The diameter of each checkpoint is to be between 0,3 and 0,5 m, and volumetric and magnetic particle checks are to be carried out unless indicated otherwise.
2. 10% selection of butts and seams and 20% at intersections. Particular attention is to be given in way of stops and starts of automatic and semi-automatic welding during fabrication.
3. Random selection to the Surveyor's satisfaction.
4. Particular attention is also given to ends of bracket connections where fitted.
5. Particular attention to be given in way of weld intersections and discontinuities at stop and start positions.
6. 10% of butts and seams and 30% at intersections. Particular attention to be taken in way of stops and starts of automatic and semi-automatic welding during fabrication.
7. 10% selection of butts and seams and 25% at intersections. Particular attention to be given in way of stops and starts of automatic and semi-automatic welding during fabrication.
8. Agreed locations are not to be indicated on blocks prior to the welding taking place, nor is any special treatment to be given at these locations.
9. Particular attention is to be given to repair rates. Additional welds are to be tested in the event that defects such as lack of fusion or incomplete penetration are repeatedly observed.

Table 8.2.2 Non-destructive examination of welds on column-stabilised and self-elevating units

Recommended extent of testing, *see* Note 9 General, *see* Note 1		
Structural item	Volumetric checkpoints	Magnetic particle checkpoints
Bracing butt and seam welds	100%	100%
Bracing weld connections to: • columns • pontoons • upper hull • lower nodes	100%	100%
Attachments to legs and bracings	—	100%
Penetrations through legs and bracings	100%	100%
Bracing shell attachment of diaphragms, gussets, stiffeners	100%	100%
Column shell butts and seams	*See* Note 4	20%
Column weld connections to: • pontoons • upper hull • in way of anchor fairleads and sheaves	100%	100%
Internal column structure connections	5%, *see* Note 5	*See* Note 3
Pontoons, hull, shell and bulkhead butts/seams	*See* Note 4	20%
Leg footings or mats	*See* Note 4	20%
Internal pontoon structure	5%, *see* Note 5	*See* Note 3
Hull penetrations, sub-sea inlets, anode and attachments, piping connection supports, etc.	100%	—
Bilge keel butts	100%	100%
Self-elevating unit leg connections • leg chords • leg trusses • leg attachments to footings or mats • butts and seams in chords and trusses	100%	100%
Upper hull: Main bulkheads/deck girders	*See* Notes 2 & 4	*See* Note 6
Strength decks and drill floor	*See* Notes 2 and 4	*See* Note 7
In way of windlasses and mooring winches	—	100%
Topside support structure connections to deck	25%	25%
Flare stack, crane pedestals and gusset connections to deck	100%	100%
Drill floor, derrick substructure and moonpool structure	*See* Notes 4 and 7	*See* Note 7
Helideck primary support, cantilevered life boat platform primary support	20%	20%
Helideck and lifeboat platform remainder	*See* Note 8	—
Other items	*See* Note 8	*See* Note 8

NOTES
1. Back-up structure of the items in question is also to be included, where applicable.
2. 100% in way of full penetration welding at end of diaphragm plates, gussets, stiffeners, etc.
3. 50% in way of fillet welds around stiffener ends, notches, cut-outs, drain hole openings, etc.
4. 10% selection of butts and seams and 20% at intersections. Particular attention to be taken in way of stops and starts of automatic and semi-automatic welding during fabrication.
5. 10% random selection of butt welds, of pontoon and column shell longitudinal stiffeners and transverse and longitudinal bulkheads stiffeners.
6. 10% random selection of fillet welds in way of stiffener ends, drain hole openings, cut-outs, notches, etc.
7. Girder and sub-structure butt welds 100% UT; principal connections to deck and main structure 100% UT and 100% MPI.
8. Random spot checks to the Surveyor's satisfaction.
9. The diameter of each checkpoint is to be between 0,3 and 0,5 m.

2.4 Fillet welds

2.4.1 Additional weld factors for structure not specifically covered by the Rules for Ships are given in Table 8.2.3.

2.4.2 Continuous welding is to be adopted in the following locations:

(a) All weldings inside tanks and peak compartments.
(b) Primary and secondary members to shell in lower hulls and stability columns.
(c) Primary and secondary members to main bracings, trusses or 'K' joints.

Table 8.2.3 Additional weld factors

Item	Weld factor	Remarks
(1) General application:		
(a) Shell boundaries of columns to lower and upper hulls	full penetration	except as required below
(b) Internal watertight or oiltight plate boundaries	0,34	generally, but alternative proposals will be considered in specific areas
(2) (a) Upper hull framing and hull framing on self-elevating units:		
(i) Webs of web frames and stringers:		
• to shell	0,16	
• to face plate	0,13	
(ii) Tank side brackets to shell and inner bottom	0,34	
(b) Primary hull framing and girders on lower hulls, columns and caissons of column-stabilised units		to be in accordance with the Rules for Ships
(3) Decks and supporting structure: Primary deck girders and connections between primary members on column-stabilised units		generally to comply with the Rules for Ships, but full penetration welding may be required
(4) Self-elevating units:		
(a) Leg construction, general	full penetration	
(b) Leg connections to footings or mats	full penetration	
(c) Internal webs, girders and bulkheads in footings and mats	0,44	full penetration may be required
(d) Internal stiffeners in footings and mats	0,34	
(e) Jackhouses, general	0,44	full penetration may be required
(f) Bulkheads and primary structures in way of leg wells	0,44	full penetration may be required
(5) Main bracings and 'K' joints, etc.:		
(a) Ring frames, girders and stiffeners	full penetration	generally, but alternative proposals may be considered
(b) Shell boundaries and end connections including brackets, gussets and cruciform plates	full penetration	
(6) Miscellaneous structures, fittings and equipment:		
(a) Rings and coamings for manhole type covers to shell on stability columns and lower hulls	full penetration	generally, but alternative proposals may be considered
(b) Rings for manhole type covers, to deck or bulk head	0,34	
(c) Frames of watertight and weathertight bulk head doors	0,34	
(d) Stiffening of doors	0,21	
(e) Ventilator, air pipes, etc., coamings to deck	0,34 0,21	Load line positions 1 and 2 elsewhere
(f) Ventilator, etc., fittings	0,21	
(g) Scuppers and discharges, to deck	0,44	
(h) Masts, derrick posts, crane pedestals, etc., to deck	0,44	full penetration welding may be required
(j) Deck machinery seats to deck	0,21	generally
(k) Mooring equipment seats and fairleads	0,44	full penetration welding may be required
(l) Bulwark stays to deck	0,21	
(m) Bulwark attachment to deck	0,34	
(n) Guard rails, stanchions, etc., to deck	0,34	
(o) Bilge keel ground bars to shell	0,34	continuous fillet weld, minimum throat thickness 4 mm
(p) Bilge keels to ground bars	0,21	light continuous or staggered intermittent fillet weld, minimum throat thickness 3 mm
(q) Fabricated anchors	full penetration	

2.5 Welding of tubular members

2.5.1 Welding is to comply with agreed Internationally or Nationally accepted Codes such as AWS or API and all welding generally is to conform to the following:

(a) All steel is to be joined by complete penetration groove welds.
(b) Unless single sided welding has been agreed for the particular weld configuration, double sided welds are to be used, wherever practicable.
(c) In lattice type structures, a minimum weld attachment length at the cord of 1,5 times the brace wall thickness is required at all locations. This is based on fatigue considerations.
(d) Care is to be taken to ensure the weld surface profile is smooth and blends with the parent material.
(e) Backing strips are not to be used unless specially agreed with LR.
(f) Root gaps are to be generally in the range of 3 to 6 mm.
(g) Bevels are to be such that the included angle is in the range 45° to 60°. However, when the dihedral angle is less than 45°, the included angle may be reduced as indicated for locations 4 and 5, *see* Fig. 8.2.2.
(h) Where saddle weld toe grinding has been agreed as a method of improving fatigue life, at the locations agreed, the grinding of the weld toe is to produce a smooth transition between the weld and the parent plate. The grinding should remove all defects, slag inclusions and any undercut. Overgrinding into the parent plate is not to exceed 2 mm or 0,05 times the plate thickness, whichever is less. The grinding tool should preferably have a spherical head (e.g., a tungsten carbide burr) and, in general, disc-grinders are to be avoided except for initial heavy grinding. Any marks made by rotation of the grinding tool are to be aligned with the direction of stress. The surface of the main body of the weld may be dressed to produce a better concave profile if the as-welded profile is poor, *see* Fig. 8.2.1 and Fig. 8.2.8. Care must be exercised in order that overgrinding does not excessively reduce the size of the attachment weld and in no case less than that required by the Rules.

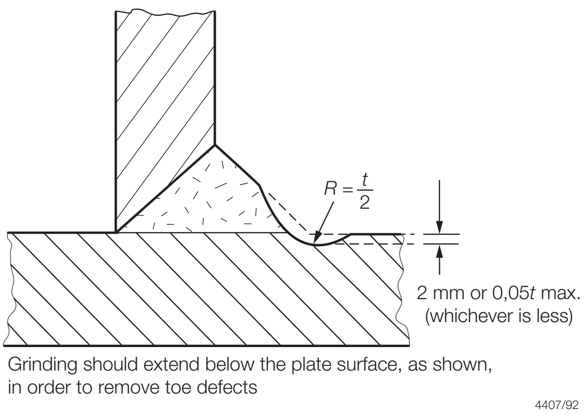


Fig. 8.2.1 Grinding of weld toe

2.5.2 Locations 1, 2, 3, 4 and 5 are related to the local dihedral angle (the angle between the brace wall and chord wall). Transition from one detail to another is to be by gradual uniform level preparation and surface profile, *see* Fig. 8.2.2.

Location	Applicable range of local dihedral angle ψ	Fig. No.
1	180° – 135°	8.2.3
2	150° – 90°	8.2.4
3	90° – 50°	8.2.5
4	75° – 30°	8.2.6
5	40° – 15°	8.2.7

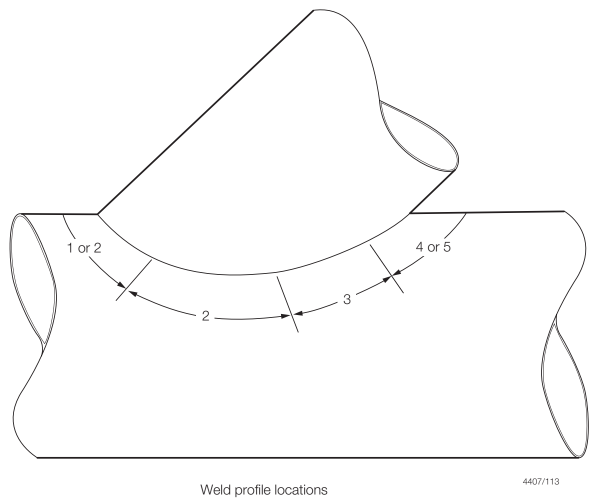


Fig. 8.2.2
Local dihedral angle for weld profile locations

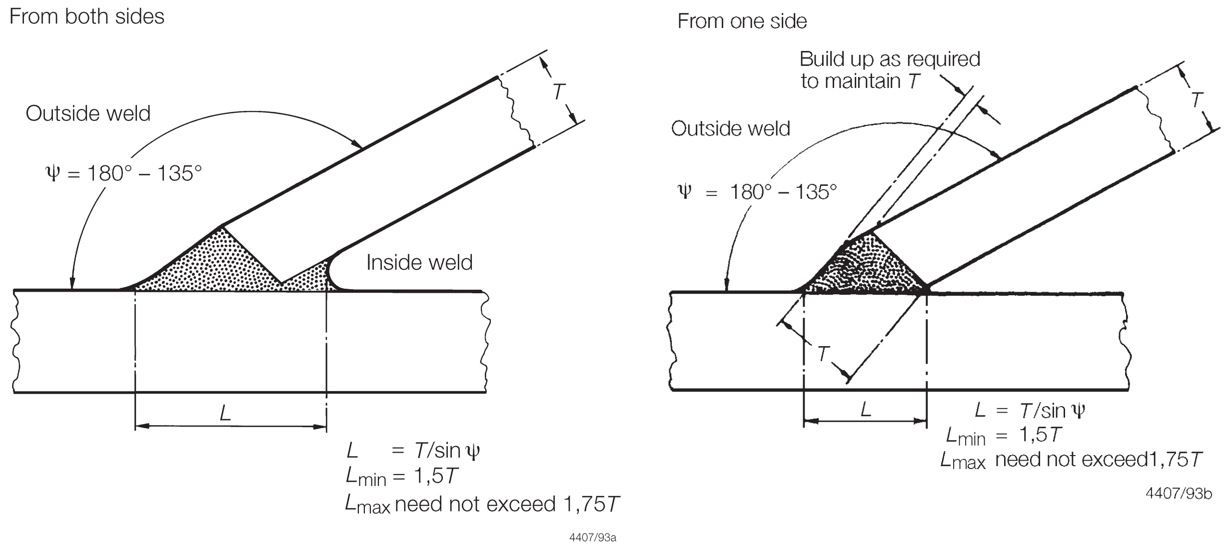


Fig. 8.2.3 Welding at location 1

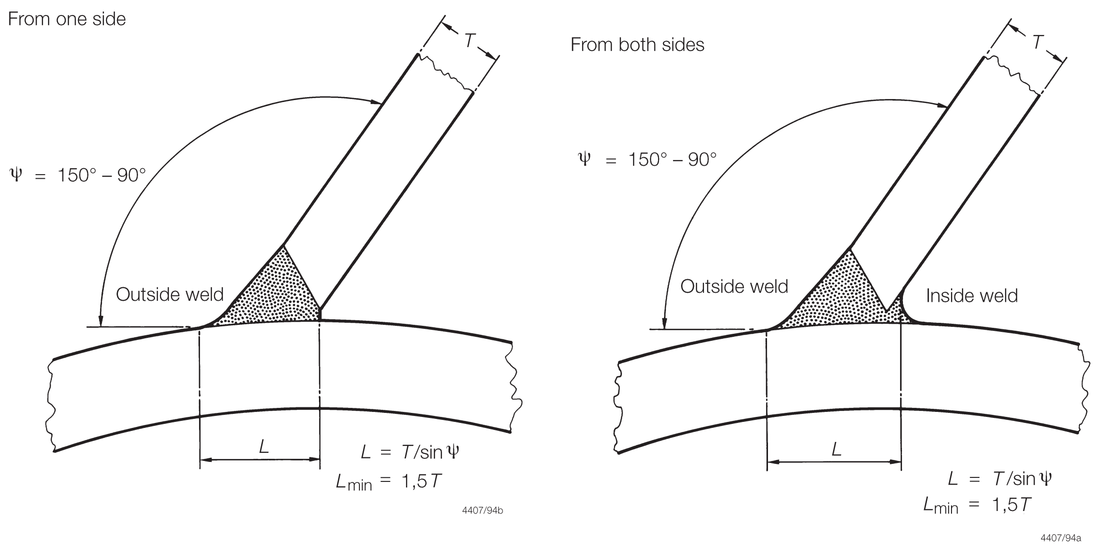


Fig. 8.2.4 Welding at location 2

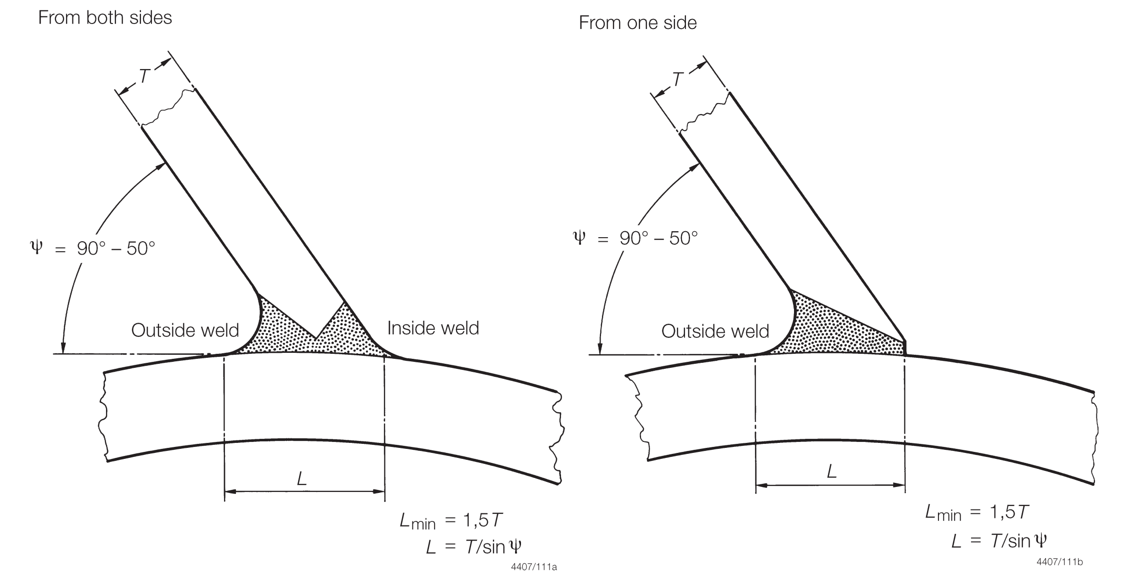


Fig. 8.2.5 Welding at location 3

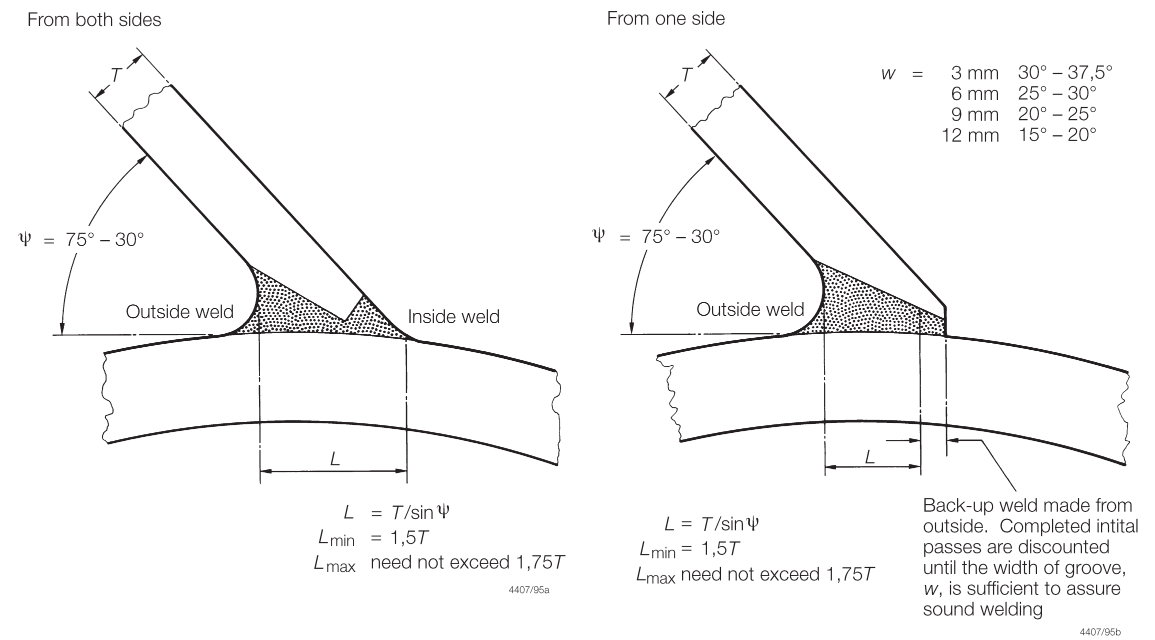


Fig. 8.2.6 Welding at location 4

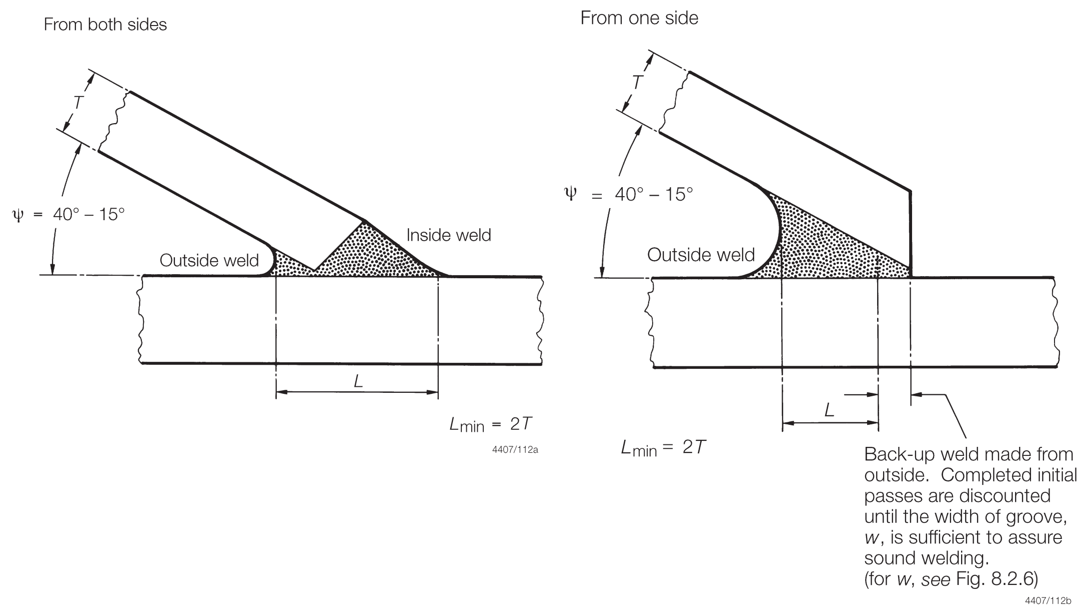


Fig. 8.2.7 Welding at location 5

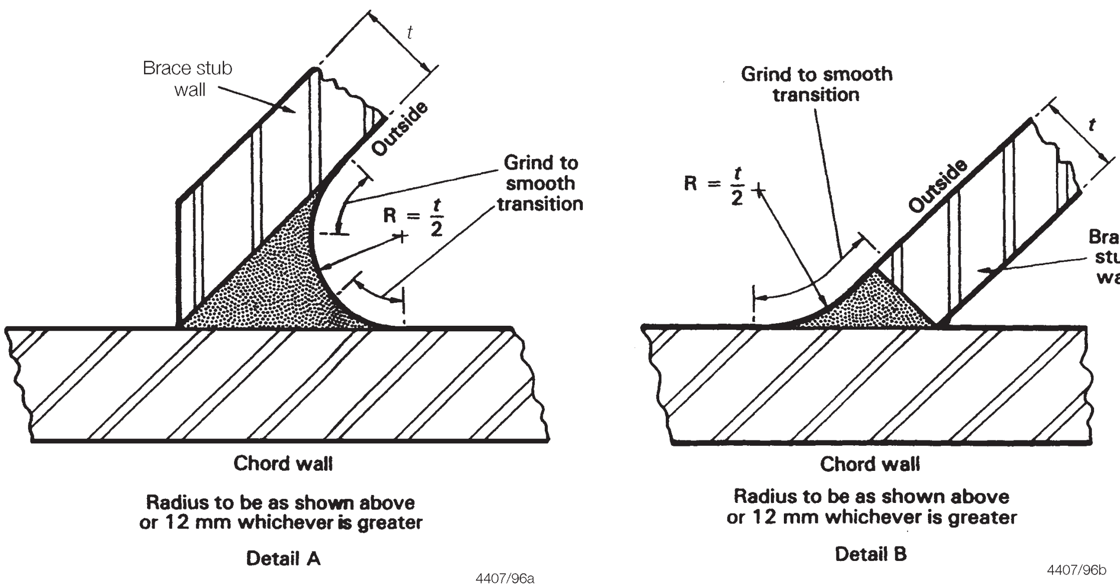


Fig. 8.2.8 Weld grinding

Section 3
Secondary member end connections

3.1 General

3.1.1 Requirements relating to secondary member end connections are given in Pt 3, Ch 10,3 of the Rules for Ships which should be complied with.

Section 4
Construction details for primary members

4.1 General

4.1.1 Requirements relating to construction details for primary members are given in Pt 3, Ch 10,4 of the Rules for Ships, which should be complied with.

4.1.2 Additional requirements with respect to unit types as indicated in this Section should also be complied with, as applicable.

4.2 Geometric properties and proportions

4.2.1 The minimum web thickness of primary shell members in the lower hulls of column-stabilised units is to be not less than $0{,}017S_w$, where S_w is spacing of stiffeners on member web, or depth of unstiffened web, in mm.

Section 5
Structural details

5.1 General

5.1.1 Requirements relating to structural details are given in Pt 3, Ch 10,5 of the Rules for Ships, which should be complied with.

5.1.2 Additional requirements with respect to unit types as indicated in this Section should also be complied with, as applicable.

5.2 Arrangements at intersections of continuous secondary and primary members

5.2.1 In the lower hulls of column-stabilised units, where primary member webs are slotted for the passage of secondary members, web stiffeners are generally to be fitted normal to the face plate of the member to provide adequate support for the loads transmitted. The ends of web stiffeners are to be attached to the secondary members.

5.2.2 Web stiffeners may be flat bars of thickness, t_w, with a minimum depth of $0{,}08d_w$ or 75 mm, whichever is the greater. Alternative sections of equivalent moment of inertia may be adopted. The direct stress in the web stiffeners is to be determined in accordance with the Rules for Ships.

5.2.3 For units other than surface type, direct stress in the vertical web stiffener and the shear stresses in the lug, collar plate and weld connections are to satisfy the factors of safety given in Ch 5,2.1.1(a).

5.2.4 For units other than surface type, the head h_1 used to calculate load transmitted to connections of secondary members is to be obtained from the following, as applicable:
(a) h_o from Table 6.3.1 in Chapter 6.
(b) h_T from Table 6.3.4 in Chapter 6.
(c) h_4 from Table 6.7.1 in Chapter 6.

5.3 Openings

5.3.1 Penetrations in main bracing members are to be avoided as far as possible. Details of essential penetrations or openings in main bracing members are to be submitted for consideration.

5.4 Other fittings and attachments

5.4.1 Gutterway bars at the upper deck are to be so arranged that the effect of main hull stresses on them is minimised and the material grade and quality of the bar are to be to the same standard as the deck plate to which it is attached.

5.4.2 Where attachments are made to rounded gunwale plates, special consideration will be given to the required grade of steel, taking into account the intended structural arrangement and attachment details. In general, the material grade and the quality of the attachment are to be to the same standard as the gunwale plates.

5.4.3 Fittings and attachments to main bracing members are to be avoided as far as possible. Where they are necessary, full details are to be submitted for consideration.

Section 6
Fabrication tolerances

6.1 General

6.1.1 All fabrication tolerances are to be in accordance with good shipbuilding practice and be agreed with LR before fabrication is commenced. Where appropriate, tolerances are to comply with a National Standard. In general, the tolerances for the fabrication of structural members for fatigue sensitive areas are to comply with the requirements of this Section.

6.1.2 For cylindrical members, the out of roundness is not to exceed 0,5 per cent of the true mean radius or 25 mm of the true mean internal diameter, whichever is the lesser.

6.1.3 When measuring cylindrical members, the out of roundness is to be measured always as a deviation from the true mean radius in order to avoid errors.

6.1.4 Cylindrical members are not to deviate from straightness by 3 mm or l mm, whichever is the greater, where l is the length of the member, in metres.

6.1.5 The misalignment of plate edges in butt welds is not to exceed the lesser of the following values:

- Special structure 0,1t or 3 mm
- Primary structure 0,15t or 3 mm
- Secondary structure 0,2t or 4 mm

where

t = thickness of the thinnest plate, in mm.

6.1.6 Misalignment of non-continuous plates such as cruciform joints is not to exceed the lesser of the following values:

- Special structure 0,2t or 4 mm
- Primary structure 0,3t or 4 mm
- Secondary structure 0,5t or 5 mm

where

t = thickness of the thinnest plate, in mm.

6.1.7 Plate deformation measured at the mid point between stiffeners or support points is not to exceed the lesser of the following values:

- Special structure $\frac{s}{200}$ mm
- Primary structure $\frac{s}{130}$ or t mm
- Secondary structure $\frac{s}{80}$ or t mm

where

s = stiffener spacing or unsupported panel width, in mm

t = plate thickness, in mm.

■ *Section 1* Anchoring equipment

1.1 General

1.1.1 To be assigned the figure **(1)** in the character of Classification, the anchoring equipment, i.e., anchors, cables, windlass and winches, etc., necessary for the unit during ocean voyages or location moves, is to be as required by this Section. The Regulations governing the assignment of the figure **(1)** for equipment are given in Pt 1, Ch 2,2.

1.1.2 When the equipment fitted to the unit is designed primarily as positional mooring equipment, consideration will be given to accepting the proposed equipment as equivalent to the Rule requirements but only if the arrangements are such that it can be efficiently used as anchoring equipment. *See also* Pt 1, Ch 2,2.3.3 and Pt 3, Ch 10.

1.1.3 Where the Classification Committee has agreed that anchoring and mooring equipment need not be fitted in view of the particular service of the unit, the character letter **N** will be assigned, *see also* Pt 1, Ch 2,2.2.2.

1.2 Equipment number

1.2.1 The requirement for anchors, cables, wires and ropes is to be based on an Equipment Number calculated as follows:

$$\text{Equipment Number} = \Delta^{2/3} + 2{,}0A_1 + \frac{A_2}{10}$$

where

Δ = moulded displacement in transit condition, in tonnes

A_1 = projected area perpendicular to wind direction when at anchor, in m^2

A_2 = projected area parallel to wind direction when at anchor, in m^2

In calculating the areas A_1 and A_2:

- Masking effect can be taken into account for columns;
- Open trusswork of derricks, booms and towers, etc., may be approximated by taking 30 per cent of the block area of each side, i.e., 60 per cent of the projected area of one side for double sided trusswork.
- When calculating projected areas, account is to be taken of topside process facilities. Special consideration will be given to structure extending outside of the Rule length, *L*.

1.3 Determination of equipment

1.3.1 The basic equipment of anchors and cables is to be determined from Table 9.1.1 and associated notes. Table 9.1.1 is based on the following assumptions:

(a) The anchors will be high holding power anchors of an approved design, *see* 1.5.

(b) The chain cable will be in accordance with the requirements of 1.6.

1.3.2 Where the equipment is based on 1.1.2, the sizes of individual anchors are not to exceed the values given in Table 9.1.1 by more than seven per cent unless the cable sizes are increased as appropriate.

1.3.3 Where the equipment is based on 1.1.2, the minimum cable strength is to be maintained and 1.7.6 is also to be complied with.

1.4 Anchors

1.4.1 Two anchors are to be fitted and arranged so that they may be readily dropped should an emergency occur.

1.4.2 The mass of each anchor is to be as given in Table 9.1.1 except that one anchor may weigh seven per cent less than the Table weight so long as the total weight of the two anchors attached to the cables is not less than twice the tabular weight for one anchor.

1.4.3 Anchors are to be of approved design. The design of all anchor heads is to be such as to minimise stress concentrations, and in particular, the radii on all parts of cast anchor heads are to be as large as possible, especially where there is a considerable change of section.

1.4.4 Positional mooring anchors of the type which are generally similar to conventional marine anchors but which must be specially laid the right way up, or which require the fluke angle or profile to be adjusted for varying types of sea bed, will not normally be accepted as anchoring equipment in accordance with these Rules.

1.4.5 If ordinary ship type stockless bower anchors, not approved as high holding power anchors, are to be used as Rule equipment, the mass of each anchor is to be not less than 1,33 times that listed in Table 9.1.1 for the unit's Equipment Number.

1.4.6 The requirements for manufacture, proof testing and identification of anchors are to be in accordance with Chapter 10 of the Rules for Materials.

Table 9.1.1 Equipment – Anchors and chain cables

Equipment number		Equipment Letter	High holding power anchor mass, in kg	Stud link chain cable			
Exceeding	Not exceeding			Length per anchor, in metres	Diameter, in mm		
					Grade U1	Grade U2	Grade U3
50	70	A	140	110	14	12,5	–
70	90	B	180	110	16	14	–
90	110	C	230	110	17,5	16	–
110	130	D	270	110	19	17,5	–
130	150	E	310	137,5	20,5	17,5	–
150	175	F	360	137,5	22	19	–
175	205	G	430	137,5	24	20,5	–
205	240	H	500	137,5	26	22	20,5
240	280	I	590	165	28	24	22
280	320	J	680	165	30	26	24
320	360	K	770	165	32	28	24
360	400	L	860	192,5	34	30	26
400	450	M	970	192,5	36	32	28
450	500	N	1080	192,5	38	34	30
500	550	O	1190	192,5	40	34	30
550	600	P	1300	220	42	36	32
600	660	Q	1440	220	44	38	34
660	720	R	1580	220	46	40	36
720	780	S	1710	220	48	42	36
780	840	T	1850	220	50	44	38
840	910	U	1990	220	52	46	40
910	980	V	2140	247,5	54	48	42
980	1060	W	2290	247,5	56	50	44
1060	1140	X	2470	247,5	58	50	46
1140	1220	Y	2660	247,5	60	52	46
1220	1300	Z	2840	247,5	62	54	48
1300	1390	A†	3040	247,5	64	56	50
1390	1480	B†	3240	275	66	58	50
1480	1570	C†	3440	275	68	60	52
1570	1670	D†	3670	275	70	62	54
1670	1790	E†	3940	275	73	64	56
1790	1930	F†	4210	275	76	66	58
1930	2080	G†	4500	275	78	68	60
2080	2230	H†	4840	302,5	81	70	62
2230	2380	I†	5180	302,5	84	73	64
2380	2530	J†	5510	302,5	87	76	66
2530	2700	K†	5850	302,5	90	78	68
2700	2870	L†	6230	302,5	92	81	70
2870	3040	M†	6530	302,5	95	84	73
3040	3210	N†	6980	330	97	84	76
3210	3400	O†	7430	330	100	87	78
3400	3600	P†	7880	330	102	90	78
3600	3800	Q†	8330	330	105	92	81
3800	4000	R†	8780	330	107	95	84
4000	4200	S†	9250	330	111	97	87
4200	4400	T†	9700	357,5	114	100	87
4400	4600	U†	10 100	357,5	117	102	90
4600	4800	V†	10 600	357,5	120	105	92
4800	5000	W†	11 000	371,5	122	107	95
5000	5200	X†	11 600	371,5	124	111	97
5200	5500	Y†	12 100	371,5	127	111	97
5500	5800	Z†	12 700	371,5	130	114	100
5800	6100	A*	13 400	371,5	132	117	102
6100	6500	B*	14 100	371,5	–	120	107
6500	6900	C*	15 000	385	–	124	111
6900	7400	D*	16 000	385	–	127	114
7400	7900	E*	17 500	385	–	132	117
7900	8400	F*	18 500	385	–	137	122
8400	8900	G*	19 500	385	–	142	127
8900	9400	H*	20 500	385	–	147	132
9400	10000	I*	22 000	385	–	152	132
10 000	10 700	J*	23 500	385	–	157	137
10 700	11 500	K*	25 000	385	–	157	142
11 500	12 400	L*	26 500	385	–	162	147
12 400	13 400	M*	29 000	385	–	–	152
13 400	14 600	N*	31 500	385	–	–	157
14 600	16 000	O*	34 500	385	–	–	162

NOTES
1. Consideration will be given to the acceptance of equipment differing from these requirements on units which are classed for restricted service (generally those with geographical limitations ensuring service in sheltered or shallow waters only).
2. Special consideration will be given to units which are unmanned during towed voyages and transfer moves.

1.5 High holding power anchors

1.5.1 Anchors of designs for which approval is sought as high holding power anchors are to be tested at sea to show that they have holding powers of at least twice those of approved standard stockless anchors of the same mass.

1.5.2 If approval is sought for a range of sizes, then at least two sizes are to be tested. The smaller of the two anchors is to have a mass not less than one tenth of that of the larger anchor, and the larger of the two anchors tested is to have a mass not less than one tenth of that of the largest anchor for which approval is sought.

1.5.3 The tests are to be conducted on not less than three different types of bottom, which should normally be soft mud or silt, sand or gravel, and hard clay or similarly compacted material.

1.5.4 The test should normally be carried out from a tug, and the pull measured by dynamometer or derived from recently verified curves of tug rev/min against bollard pull. A scope of 10 is recommended for the anchor cable, which may be wire rope for this test, but in no case should a scope of less than six be used. The same scope is to be used for the anchor for which approval is sought and the anchor that is being used for comparison purposes.

1.5.5 High holding power anchors are to be of a design that will ensure that the anchors will take effective hold of the sea bed without undue delay and will remain stable, for holding forces up to those required by 1.5.1, irrespective of the angle or position at which they first settle on the sea bed when dropped from a normal type of hawse pipe. In case of doubt, a demonstration of these abilities may be required.

1.6 Chain cables

1.6.1 The minimum sizes and lengths of chain cables are to be as required by Table 9.1.1.

1.6.2 Chain cables may be of mild steel, special quality steel or extra quality steel in accordance with the requirements of Chapter 10 of the Rules for Materials and are to be graded in accordance with Table 9.1.2.

Table 9.1.2 Anchoring equipment chain grades

Grade	Material	Tensile strength	
		N/mm^2	kgf/mm^2
U1	Mild steel	300–490	(31–50)
U2(a)	Special quality steel (wrought)	490–690	(50–70)
U2(b)	Special quality steel (cast)	490–690	(50–70)
U3	Extra special quality steel	690 min.	(70 min.)

1.6.3 Grade U1 material having a tensile stress of less than 400 N/mm^2 (41 kgf/cm^2) is not to be used in association with high holding power anchors. Grade U3 material is to be used only for chain 20,5 mm or more in diameter.

1.6.4 The form and proportion of links and shackles are to be in accordance with Chapter 10 of the Rules for Materials.

1.6.5 As an alternative to the chains listed in Table 9.1.1, consideration will be given to the use of the following:
- Chain cables of Grades R3, R3S and R4 in accordance with Ch 10,3 of the Rules for Materials.
- Wire rope meeting the requirements of the Rules for Materials.

In this case, the length and breaking strength of the wire rope will be specially considered.

1.7 Arrangements for working and stowing anchors and cables

1.7.1 A windlass or winch of sufficient power and suitable for the type of cable is to be provided for each of the anchor cables. Where Owners require equipment significantly in excess of Rule requirements, it is their responsibility to specify increased windlass or winch power.

1.7.2 The windlasses or winches are to be securely fitted and efficiently bedded to suitable positions on the unit. The structural design integrity of the bedplate is the responsibility of the Builder and windlass manufacturer.

1.7.3 The following performance criteria are to be used as a design basis for the windlass:

(a) The windlass is to have sufficient power to exert a continuous duty pull over a period of 30 minutes of:
$36,79 d_c^2$ N ($3,75 d_c^2$ kgf) – for Grade U1 chain,
$41,68 d_c^2$ N ($4,25 d_c^2$ kgf) – for Grade U2 chain,
$46,6 d_c^2$ N ($4,75 d d_c^2$ kgf) – for Grade U3 chain,
where d_c is the chain diameter, in mm.

(b) The windlass is to have sufficient power to exert, over a period of at least two minutes, a pull equal to the greater of:
(i) short-term pull:
1,5 times the continuous duty pull as defined in 1.7.3(a).
(ii) anchor breakout pull:

$$16,24 W_a + \frac{14,0 l_c\, d_c^2}{100} \text{ N}$$

$$\left(1,65 W_a + \frac{14,2 l_c\, d_c^2}{1000} \text{ kgf} \right)$$

where
l_c is length of chain cable per anchor, in metres, as given by Table 9.1.1
W_a is the mass of high holding power anchor, in kg, as given in Table 9.1.1

(c) The windlass, with its braking system in action and in conditions simulating those likely to occur in service, is to be able to withstand, without permanent deformation or brake slip, a load, applied to the cable, given by:

$K_b d_c^2$ $(44 - 0{,}08d_c)$ N

($K_b d_c^2$ $(44 - 0{,}08d_c)$ kgf)

where

K_b is given in Table 9.1.3.

NOTE

The performance criteria are to be verified by means of shop tests in the case of windlasses manufactured on an individual basis. Windlasses manufactured under LR's *Type Approval Scheme* will not require shop testing on an individual basis.

Table 9.1.3 Windlass braking factors

Cable grade	K_b	
	Windlass used in conjunction with chain stopper	Chain stopper not fitted
U1	4,41 (0,45)	7,85 (0,8)
U2	6,18 (0,63)	11,0 (1,12)
U3	8,83 (0,9)	15,7 (1,6)

1.7.4 Where shop testing is not possible and Type Approval has not been obtained, calculations demonstrating compliance with 1.7.3 are to be submitted, together with detailed plans and an arrangement plan showing the following components:

- Shafting.
- Gearing.
- Brakes.
- Clutches.

1.7.5 During trials on board the unit, the windlass should be shown to be capable of raising the anchor from a depth of 82,5 m to a depth of 27,5 m at a mean speed of not less than 9 m/min. Where the depth of water in the trial area is inadequate, suitable equivalent simulating conditions will be considered as an alternative.

1.7.6 The cable is to be capable of being paid out in the event of a power failure.

1.7.7 Windlass performance characteristics specified in 1.7.3 and 1.7.5 are based on the following assumptions:

- One cable lifter only is connected to the drive shaft.
- Continuous duty and short-term pulls are measured at the cable lifter.
- Brake tests are carried out with the brakes fully applied and the cable lifter declutched.
- The probability of declutching a cable lifter from the motor with its brake in the off position is minimised.
- Hawse pipe efficiency assumed to be 70 per cent.

1.7.8 An easy lead of the cables from the windlass or winch to the anchors and chain lockers or wire storage drum is to be arranged. Where cables pass over or through stoppers, these stoppers are to be manufactured from ductile material and be designed to minimise the probability of damage to, or snagging of, the cable. They are to be capable of withstanding without permanent deformation a load equal to 80 per cent of the Rule breaking load of the cable passing over them.

1.7.9 The chain locker is to be of a capacity and depth adequate to provide an easy direct lead for the cable into the chain pipes, when the cable is fully stowed. Chain or spurling pipes are to be of suitable size and provided with chafing lips. If more than one chain is to be stowed in one locker then the individual cables are to be separated by substantial divisions in the locker.

1.7.10 Provision is to be made for securing the inboard ends of the cables to the structure. This attachment should have a working strength of not less than 63,7 kN (6,5 tonne-f) or 10 per cent of the breaking strength of the chain cable, whichever is the greater, and the structure to which it is attached is to be adequate for this load. Attention is drawn to the advantages of arranging that the cable may be slipped in an emergency from an accessible position outside the chain locker.

1.7.11 Where wire rope cables are used, these are to be stored on suitable drums. The lead to the drums is to be such that the cables will reel onto the drums reasonably evenly. If the drums are designed to apply the full winch hauling load to the cables then the arrangements, using spooling gear or otherwise, are to ensure even reeling of the cables onto the drums.

1.7.12 Fairleads, hawse pipes, anchor racks and associated structure and components are to be of ample thickness and of a suitable size and form to house the anchors efficiently, preventing, as much as practicable, slackening of the cable or movements of the anchor being caused by wave action. The plating and framing in way of these components are to be reinforced as necessary. Columns, lower hulls, footings and other areas likely to be damaged by anchors, chain cables and wire ropes, etc., are to be suitably strengthened.

1.7.13 The design of the windlass is to be such that the following requirements or equivalent arrangements will minimise the probability of the chain locker or forecastle being flooded in bad weather:

- a weathertight connection can be made between the windlass bedplate, or its equivalent, and the upper end of the chain pipe;
- access to the chain pipe is adequate to permit the fitting of a cover or seal, of sufficient strength and proper design, over the chain pipe if the sea is liable to break over the windlass; and
- for column-stabilised units, *see* Ch 7,4.7.2.

1.8 Testing of equipment

1.8.1 All anchors and chain cables are to be tested at establishments and on machines recognised by LR and under the supervision of LR's Surveyors or other Officers recognised by LR, and in accordance with the Rules for Materials.

1.8.2 Test certificates showing particulars of weights of anchors, or size and weight of cable and of the test loads applied are to be furnished. These certificates are to be examined by the Surveyors when the anchors and cables are placed on board the unit.

1.8.3 Steel wire ropes are to be tested as required by the Rules for Materials.

■ *Section 2* Towing arrangements

2.1 General

2.1.1 All non-self-propelled units and other units not designed for unassisted sea passages are to be provided with adequate arrangements for towing.

2.1.2 Plans and full particulars of the unit's towing facilities are to be submitted for approval, together with calculations or model test data supporting the assigned system design load. The maximum permitted static bollard pull for each towing arrangement is to be stated on the plans.

2.1.3 Particulars of the towing system, its design load and the operational instructions are to be incorporated in the Operations Manual.

2.2 Towing system

2.2.1 Units are to be provided with a main towing system suitable for towing with one or two towing vessels and in addition it is recommended that an emergency towing system is provided.

2.2.2 The emergency towing system may be arranged by using the unit's anchor line or similar system.

2.2.3 The main towing system is to be suitable for the design load in accordance with 2.1.2 but is not to be taken less than 75 tonne-f.

2.2.4 The components of the towing system are to be manufactured and tested in accordance with Chapter 10 of the Rules for Materials.

2.2.5 The main towing system is to consist of not less than the following parts:

- Two attachments to the unit (e.g. towing brackets).
- Two chain/wire rope pendants connected to the unit.
- One triangular plate or equivalent.
- Two wire rope towlines as 'weak links'.
- Shackles for connections.

2.2.6 Wire ropes are to have 'hard eyes' fitted at their ends.

2.2.7 Where towing bridles can be subjected to heavy wear due to chafing, chains are to be used.

2.2.8 The attachments to the unit are to be as far apart as practicable and on column-stabilised units the attachments are to be fitted to the lower hulls.

2.2.9 The length of the towing pendants attached to the unit is not to be less than the distance between the attachments.

2.2.10 The position and arrangement of the towing attachments are to be such that it is possible to change the chain/wire towing pendant connections quickly in calm water.

2.2.11 When towing with two towing vessels, each towline (weak link) is to be fitted between the unit's towing pendants and the towlines of the towing vessels. When towing with one towing vessel, the towline (weak link) is to be connected between the triangular plate or equivalent and the towline of the towing vessel.

2.2.12 The length of each towline (weak link) is, in general, not to be less than 50 m so that the connection to the towline of the towing vessel is at a safe distance from the unit.

2.3 Strength

2.3.1 Each towing pendant connected to the unit is to have a minimum breaking strength of three times the design load, *see* 2.2.3.

2.3.2 The towline (weak link) is to have a breaking strength of approximately 85 per cent of the breaking strength of the towing pendant connected to the unit.

2.3.3 The towing pendant connections to the unit, triangular plate and shackles are to have a breaking strength greater than the strongest part of the towing system.

2.3.4 The attachments to the unit are to be designed for a towing direction of 0° to 90° off centreline port and starboard. Account is to be taken of the specified range of inclination angles.

2.3.5 Towing brackets or pad-eyes and their support structure are to be designed to the breaking strength of the attached towing pendant. The permissible stresses are to be in accordance with Ch 5,2.1.1(c).

2.4 Retrieval system

2.4.1 Means are to be provided to retrieve the unit's towing pendants or bridle in the event that the towing vessel's towline or the towline (weak link) should break.

2.5 Spare parts

2.5.1 It is recommended that an adequate number of spare parts for the towing system be provided on board during towing operations.

Section

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies to all the unit types detailed in Part 3, and requirements are given for rudders, nozzles, steering gear, tunnel thrust unit structure and stabiliser structure.

1.1.2 Where units are fitted with conventional rudders, the scantlings and arrangements are to comply with the requirements of this Chapter.

1.1.3 Where a self-propelled unit is fitted with a non-conventional rudder or the rudder is omitted, special consideration will be given to the steering system so as to ensure that an acceptable degree of reliability and effectiveness is provided in order to achieve equivalence to the normal Rule requirements.

1.2 General symbols

1.2.1 The following symbols and definitions are applicable to this Chapter, unless otherwise stated:

L, B, C_b as defined in Ch 1,5.1

σ_0 = minimum yield stress or 0,5 per cent proof stress of the material, in N/mm^2 (kgf/mm^2)

k = higher tensile steel factor, *see* Ch 2,1.2.

1.3 Navigation in ice

1.3.1 Where an ice class notation is included in the class of a unit, additional requirements are applicable as detailed in Pt 3, Ch 6.

1.4 Materials

1.4.1 The requirements for materials are contained in the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

■ *Section 2* Rudders

2.1 General

2.1.1 Requirements for rudders are given in Pt 3, Ch 13,2 of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships), which should be complied with.

2.1.2 Where an **OIWS** (In-water Survey) notation is to be assigned, *see also* Pt 1, Ch 2,2.4.9, means are to be provided for ascertaining the rudder pintles and bush clearances and for verifying the security of the pintles in their sockets with the unit afloat.

■ *Section 3* Fixed and steering nozzles

3.1 General

3.1.1 Requirements for fixed and steering nozzles are given in Pt 3, Ch 13,3 of the Rules for Ships, which should be complied with.

■ *Section 4* Steering gear and allied systems

4.1 General

4.1.1 Requirements for steering gear are given in Pt 5, Ch 19.

4.1.2 When units are fitted with steering arrangements consisting of Azimuth thrusters, *see* Pt 5, Ch 20.

■ *Section 5* Tunnel thrust unit structure

5.1 General

5.1.1 Requirements for tunnel thrust unit structure are given in Pt 3, Ch 13,5 of the Rules for Ships, which should be complied with.

5.1.2 Thrust units are to be enclosed in suitable watertight spaces to prevent flooding in the case of leakage or damage to the thrust unit.

Section 6
Stabiliser structure

6.1 General

6.1.1 Requirements for stabiliser structure are given in Pt 3, Ch 13,6 of the Rules for Ships, which should be complied with.

Section

■ *Section 1* General

1.1 Definitions

1.1.1 **Quality Assurance Scheme**. LR's Quality Assurance requirements for the hull construction of mobile offshore units are defined as follows:

(a) **Quality Assurance**. All activities and functions concerned with the attainment of quality including documentary evidence to confirm that such attainment is met.

(b) **Quality system**. The organisation structure, responsibilities, activities, resources and events laid down by Management that together provide organised procedures (from which data and other records are generated) and methods of implementation to ensure the capability of the fabrication yard to meet quality requirements.

(c) **Quality programme**. A documented set of activities, resources and events serving to implement the quality system of an organisation.

(d) **Quality plan**. A document derived from the quality programme setting out the specific quality practices, special processes, resources and activities relevant to a particular unit or series of similar units. This document will also indicate the stages at which, as a minimum, direct survey and/or system monitoring will be carried out by the Classification Surveyor.

(e) **Quality control**. The operational techniques and activities used to measure and regulate the quality of construction to the required level.

(f) **Inspection**. The process of measuring, examining, testing, gauging or otherwise comparing the item with the approved drawings and the fabrication yard's written standards, including those which have been agreed by LR for the purposes of classification of the specific type of unit concerned.

(g) **Assessment**. The initial comprehensive review of the fabrication yard's quality systems, prior to the granting of approval, to establish that all the requirements of these Rules have been met.

(h) **Audit**. A documented activity aimed at verifying by examination and evaluation that the applicable elements of the quality programme continue to be effectively implemented.

(j) **Hold point**. A defined stage of manufacture beyond which the work must not proceed until the inspection has been carried out by all the relevant personnel.

(k) **System monitoring**. The act of checking, on a regular basis, the applicable processes, activities and associated documentation that the Fabricator's quality system continues to operate as defined in the quality programme.

(l) **Special process**. A process where some aspects of the required quality cannot be assured by subsequent inspection of the processed material alone. Manufacturing special processes include welding, forming and the application of protective treatments. Inspection and testing processes classified as special processes include non-destructive examination and pressure and leak testing.

1.2 Scope of the Quality Assurance Scheme

1.2.1 This Chapter specifies the minimum Quality system requirements for a fabrication yard to construct mobile offshore units under LR's *Quality Assurance Scheme*.

1.2.2 For the purposes of this Chapter of the Rules, 'construction (hull)' comprises the primary bracings, columns, legs, footings, hull structure, appendages, superstructure, deckhouses and closing appliances, all as required by the Rules.

1.2.3 Although the requirements of this scheme are, in general, for steel structures of all welded construction, other materials for use in hull construction will be considered.

■ *Section 2* Application

2.1 Certification of the fabrication yard

2.1.1 Requirements for application are given in Pt 3, Ch 15,2 of the Rules for Ships, which should be complied with.

■ *Section 3*
Particulars to be submitted

3.1 Documentation and procedures

3.1.1 Requirements for particulars to be submitted are given in Pt 3, Ch 15,3 of the Rules for Ships, which should be complied with.

■ *Section 4*
Requirements of Parts 1 and 2 of the Scheme

4.1 General

4.1.1 Requirements for Parts 1 and 2 of the scheme are given in Pt 3, Ch 15,4 of the Rules for Ships, which should be complied with.

■ *Section 5*
Additional requirements for Part 2 of the Scheme

5.1 Quality System procedures

5.1.1 Additional requirements for Part 2 of the scheme are given in Pt 3, Ch 15,5 of the Rules for Ships, which should be complied with.

■ *Section 6*
Initial assessment of fabrication yard

6.1 General

6.1.1 Requirements for the initial assessment of the Shipyard are given in Pt 3, Ch 15,6 of the Rules for Ships, which should be complied with.

■ *Section 7*
Approval of the fabrication yard

7.1 General

7.1.1 Requirements for approval of the shipyard are given in Pt 3, Ch 15,7 of the Rules for Ships, which should be complied with.

■ *Section 8*
Maintenance of approval

8.1 General

8.1.1 Requirements for maintenance of approval are given in Pt 3, Ch 15,8 of the Rules for Ships, which should be complied with.

■ *Section 9*
Suspension or withdrawal of approval

9.1 General

9.1.1 Requirements for suspension or withdrawal of approval are given in Pt 3, Ch 15,9 of the Rules for Ships, which should be complied with.

■ *Section A1* General

A1.1 Application

A1.1.1 This Appendix contains details of acceptable design S-N curves and joint classification. The details contained in this Appendix take due account of the fatigue data published in the *UK HSE Guidance Notes for Design, Construction and Classification of Offshore Installations,* 4th edition, 1990.

A1.1.2 All tubular joints are assigned Class T. Other types of joints are assigned Class B, C, D, E, F, F2, G or W depending upon:

- geometric arrangements;
- direction of applied stress; and
- method of fabrication and inspection.

A1.1.3 Details of the design S-N curves are given in Section A2, joint classifications are given in Section A3.

A1.1.4 Guidance on the determination of global stress concentration factors is given in Section A4.

A1.1.5 Other methods may be used after special consideration and agreement with LR. Detailed proposals are to be submitted.

■ *Section A2* Fatigue design S-N curves

A2.1 Basic design S-N curves

A2.1.1 The basic design curves consist of linear relationships between $\log(S_B)$ and log(N). They are based upon a statistical analysis of appropriate experimental data and may be taken to represent two standard deviations below the mean line. Thus the basic S-N curves are of the form:

$$\log(N) = \log(K_1) - d\sigma - m\log(S_B)$$

where

N = the predicted number of cycles to failure under stress range S_B
K_1 = a constant relating to the mean S-N curve
d = the number of standard deviations below the mean
σ = the standard deviation of log N
m = the inverse slope of the S-N curve.

The relevant values of these terms are shown in Table A2.1. Table A2.1 also shows the value of K_2
where

$$\log(K_2) = \log(K_1) - 2\sigma$$

which is relevant to the basic design curves (i.e. for d = 2).

A2.2 Modifications to basic S-N curves

A2.2.1 The factors listed in this sub-Section are to be considered when using the basic S-N curve.

A2.2.2 **Unprotected joints in sea-water**. For joints without adequate corrosion protection which are exposed to sea water the basic S-N curve is reduced by a factor of two on life for all joint classes.

NOTE
For high strength steels, i.e. σ_y >400 N/mm^2, a penalty factor of two may not be adequate. In addition the correction relating to the numbers of small stress cycles is not applicable.

A2.2.3 **Effect of plate thickness**. The fatigue strength of welded joints is to some extent dependent on plate thickness, strength decreasing with increasing thickness. The basic S-N curves shown in Figs. A2.2 and A2.3 relate to thicknesses as follows:

- Nodal joints (Class T) up to 32 mm
- Non-nodal joints (Classes B-G) up to 22 mm.

For joints of other thicknesses, correction factors on life or stress have to be applied to produce a relevant S-N curve. The correction on stress range is of the form:

$$S = S_B\left(\frac{t_B}{t}\right)^{1/4}$$

where

S = the fatigue strength of the joint under consideration
S_B = the fatigue strength of the joint using the basic S-N curve
t = the actual thickness of the member under consideration
t_B = the thickness relevant to the basic S-N curve

Substituting the above relationship in the basic S-N curve equation in A2.1.1 and using the equation for $\log(K_2)$ in A2.1.1 yields the following equation of the S-N for a joint member thickness t:

$$\log(N) = \log K_2 - m\log\left(\frac{S}{\left(\frac{t_B}{t}\right)^{1/4}}\right)$$

A value of t = 22 mm should be used for calculating endurance N when the actual thickness is less than 22 mm.

NOTE
This gives a benefit for nodal joints with wall thicknesses in the range of 22 to 32 mm.

Table A2.1 Details of basic S-N curves

Class	K_1	K_1 $\log_{10}$	$\log_e$	m	Standard deviation $\log_{10}$	$\log_e$	K_2	S_o N/mm^2
B	$2{,}343 \times 10^{15}$	15,3697	35,3900	4,0	0,1821	0,4194	$1{,}01 \times 10^{15}$	100
C	$1{,}082 \times 10^{14}$	14,0342	32,3153	3,5	0,2041	0,4700	$4{,}23 \times 10^{13}$	78
D	$3{,}988 \times 10^{12}$	12,6007	29,0144	3,0	0,2095	0,4824	$1{,}52 \times 10^{12}$	53
E	$3{,}289 \times 10^{12}$	12,5169	28,8216	3,0	0,2509	0,5777	$1{,}04 \times 10^{12}$	47
F	$1{,}289 \times 10^{12}$	12,2370	28,1770	3,0	0,2183	0,5027	$0{,}63 \times 10^{12}$	40
F2	$1{,}231 \times 10^{12}$	12,0900	27,8387	3,0	0,2279	0,5248	$0{,}43 \times 10^{12}$	35
G	$0{,}566 \times 10^{12}$	11,7525	27,0614	3,0	0,1793	0,4129	$0{,}25 \times 10^{12}$	29
W	$0{,}368 \times 10^{12}$	11,5662	26,6324	3,0	0,1846	0,4251	$0{,}16 \times 10^{12}$	25
T	$4{,}577 \times 10^{12}$	12,6606	29,1520	3,0	0,2484	0,5720	$1{,}46 \times 10^{12}$	53, *see* Note 1

NOTES
1. Idealised hot spot stress
2. For example, the T curve expressed in terms of $\log_{10}$ is:
   $\log_{10}(N) = 12{,}6606 - 0{,}2484d - 3\log_{10}(S_B)$

A2.2.4 **Weld improvement**. For welded joints involving potential fatigue cracking from the weld toe, an improvement in strength by at least 30 per cent, equivalent to a factor of 2,2 on life, can be obtained by controlled local machining or grinding of the weld toe. This is to be carried out either with a rotary burr or by disc grinding. The treatment should produce a smooth concave profile at the weld toe with the depth of the depression penetrating into the plate surface to at least 0,5 mm below the bottom of any visible undercut, *see* Fig. A2.1, and ensuring that no exposed defects remain. The maximum depth of local machining or grinding is not to exceed 2 mm or five per cent of the plate thickness. In the case of a multi-pass weld more than one weld toe may need to be dressed. Where toe grinding is used to improve the fatigue life of fillet welded connections, care should be taken to ensure that the required throat size is maintained. The benefit of grinding is only applicable for welded joints which are adequately protected from sea-water corrosion. Any credit for other beneficial treatments should be justified. It is recommended that no advantage for toe grinding should be taken at the initial design stage. Overall weld profiling is preferred but no improvement in fatigue strength can be allowed unless accompanied by toe grinding. In the case of partial penetration welds, where failure may occur from the weld root, grinding of the weld toe cannot be relied upon to give an increase in strength.

A2.2.5 Special consideration will be given to alternative techniques intended to improve weld quality. Detailed proposals are to be submitted.

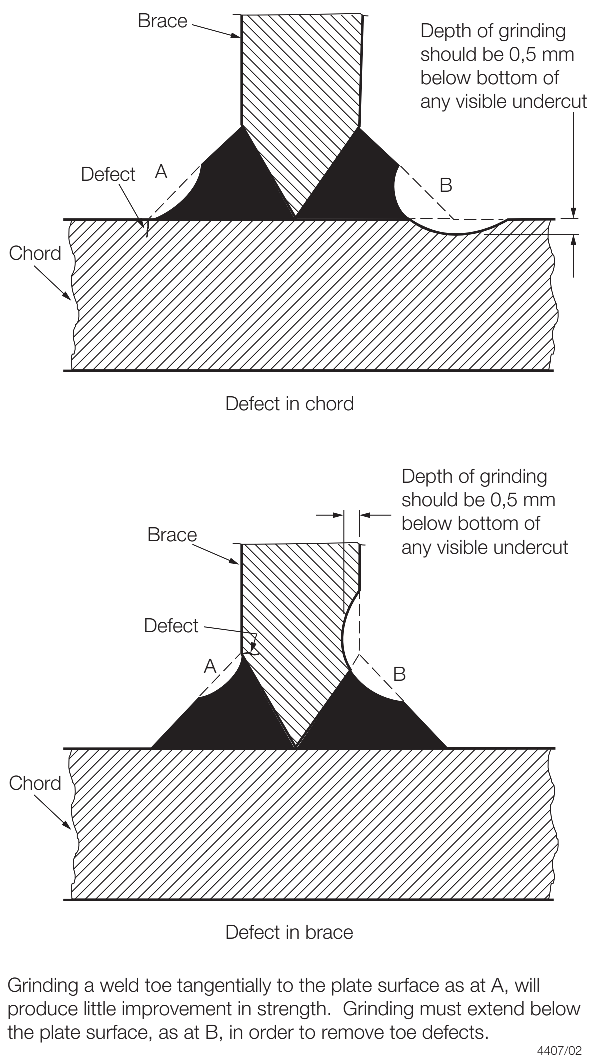


Fig. A2.1 Weld improvements

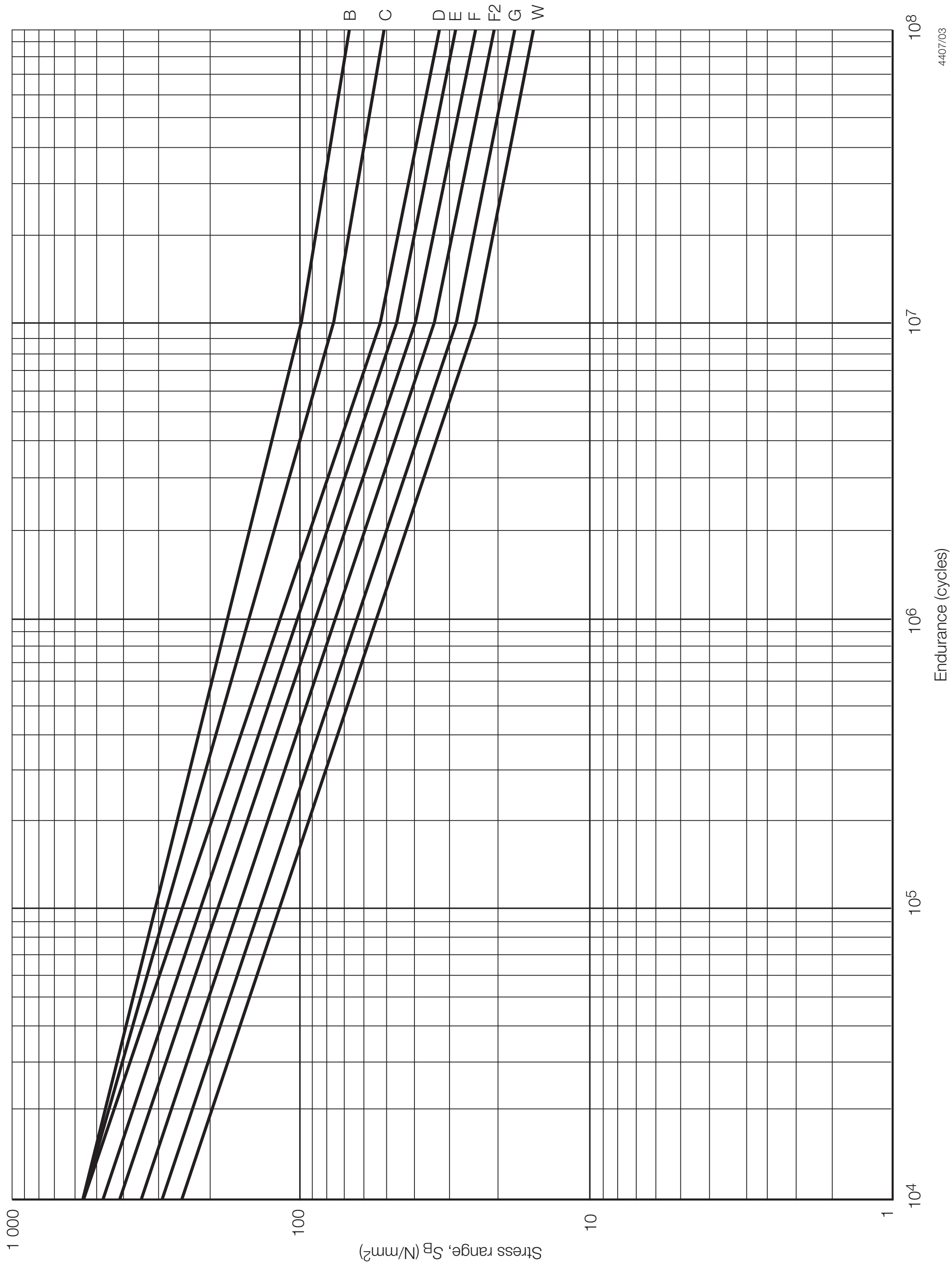


Fig. A2.2 Basic design S-N curve for non-nodal joints

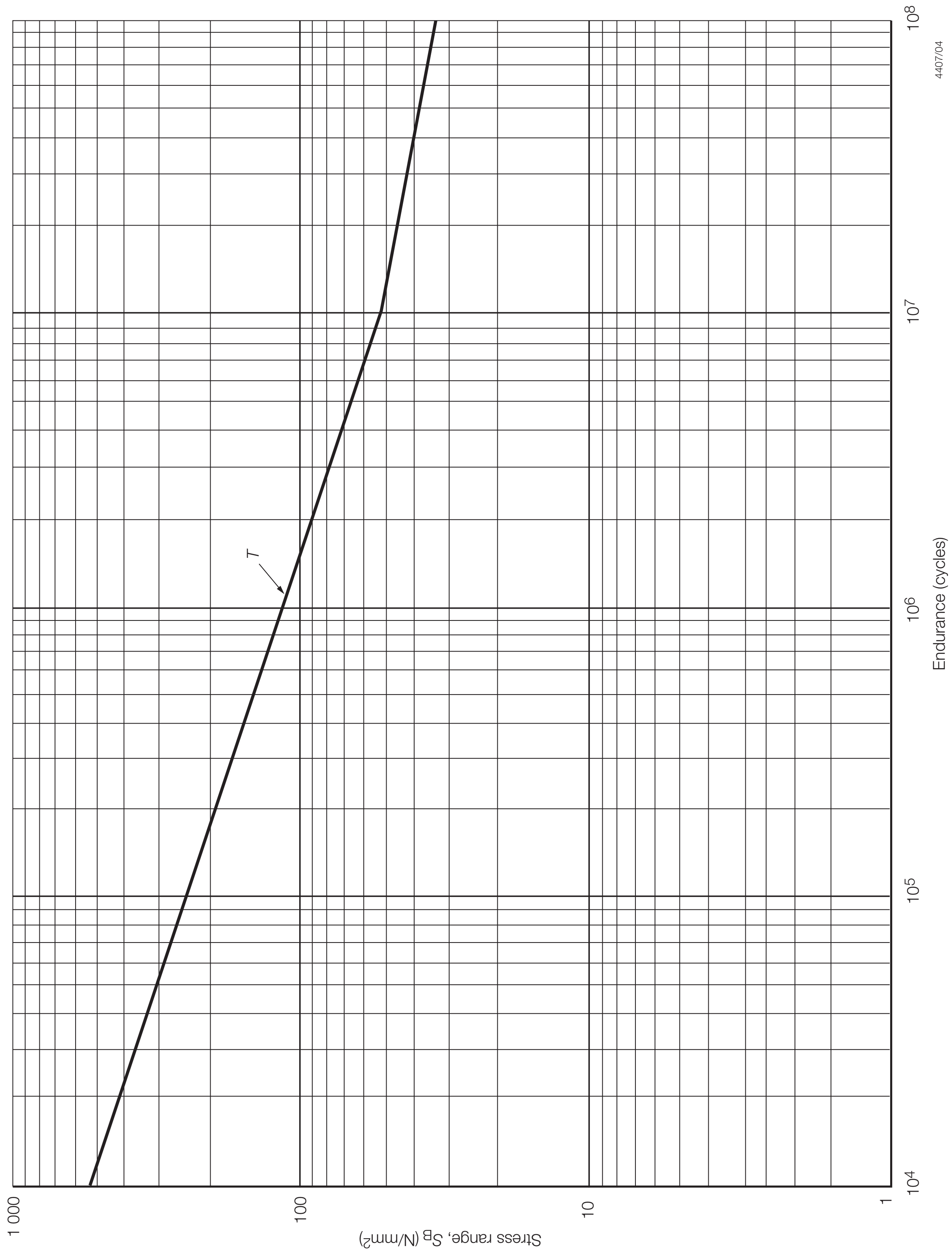


Fig. A2.3 Basic design S-N curves for nodal joints

A2.3 Treatment of low stress cycles

A2.3.1 Under constant amplitude stresses there is a certain stress range, which varies both with the environment and with the size of any initial defects, below which an indefinitely large number of cycles can be sustained. In air and sea-water with adequate protection against corrosion, and with details fabricated in accordance with this Appendix, it is assumed that this non-propagating stress range, S_o. is the stress corresponding to $N = 10^7$ cycles; relevant values of S_o are shown in Table A2.1.

A2.3.2 When the applied fluctuating stress has varying amplitude, so that some of the stress ranges are greater and some less than S_o, the larger stress ranges will cause growth of the defect, thereby reducing the value of the non-propagating stress range below S_o. In time, an increasing number of stress ranges, below S_o can themselves contribute to crack growth. The final result is an earlier fatigue failure than could be predicted by assuming that all stress ranges below S_o are ineffective.

A2.3.3 An adequate estimate of this behaviour can be made by assuming that the S-N curve has a change of inverse slope from m to $m + 2$ at $N = 10^7$ cycles. This correction does not apply in the case of unprotected joints in sea-water.

A2.4 Treatment of high stress cycles

A2.4.1 For high stress cycles the design S-N curve for nodal joints (the T curve) may be extrapolated back linearly to a stress range equal to twice the material yield stress $2\sigma_y$.

A2.4.2 An example of the high stress cycle limit for the T curve is given in Fig. A2.4.

A2.4.3 A similar procedure can be adopted for non-nodal joints (Classes B-G) where local bending or other structural stress concentrating features are involved and the relevant stress range includes the stress concentration.

A2.4.4 If the joint is in a region of simple membrane stress then the design S-N curves may be extrapolated back linearly to a stress range given by twice the tensile stress limitations given in these Rules.

A2.4.5 For the Class W curve, extrapolation may be made back as for the non-nodal joints but to a stress range defined by half the values given above (i.e. with reference to shear instead of tensile stress).

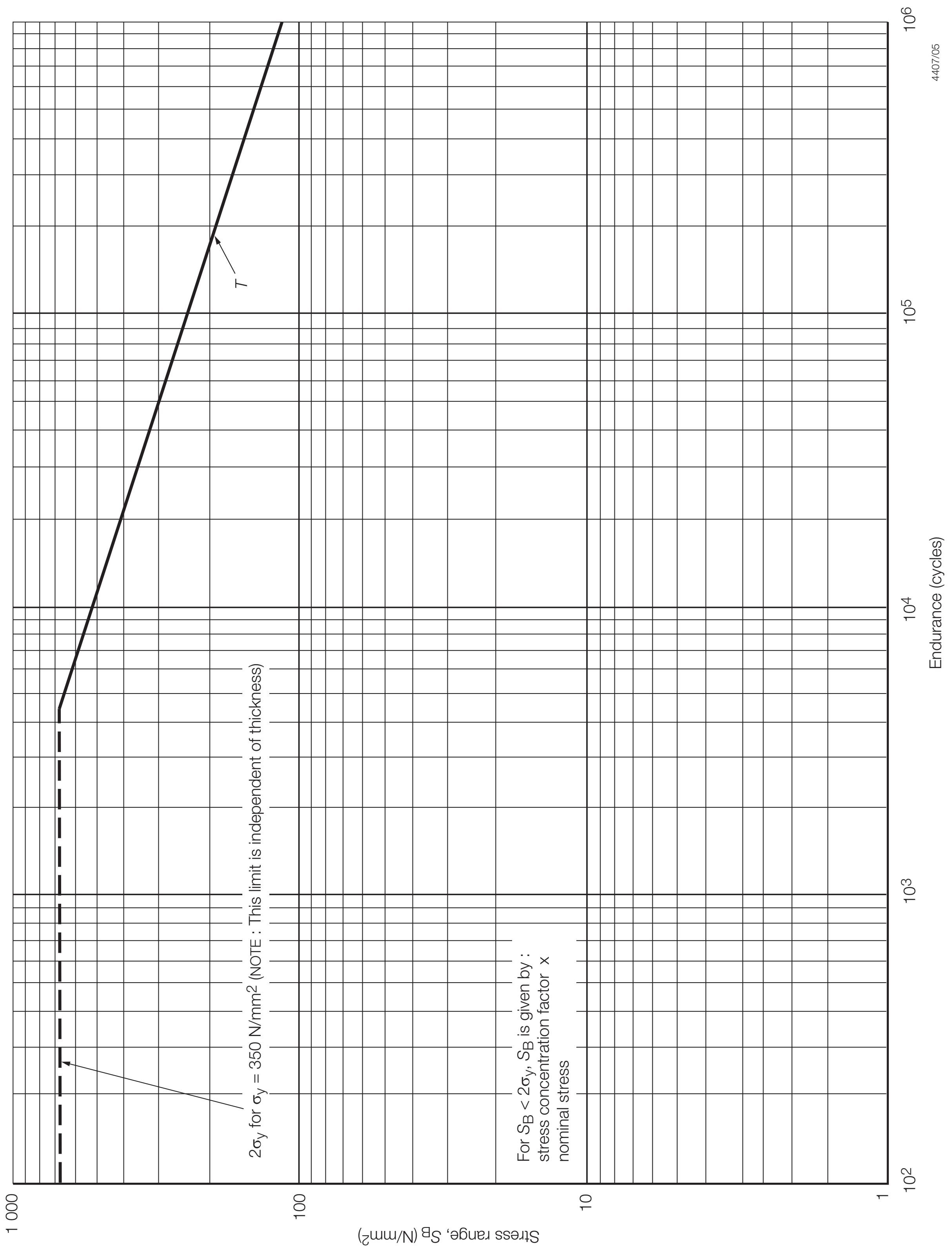


Fig. A2.4 Treatment of high cyclic stresses for the T-curve and a material with yield stress = 350 N/mm^2

■ *Section A3*
Fatigue joint classification

A3.1 General

A3.1.1 Fatigue joint classification details including notes on mode of failure and typical examples are given in Table A3.1.

Table A3.1 Fatigue joint classification (*see continuation*)

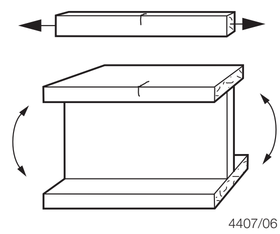
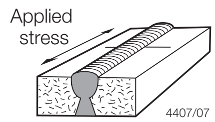
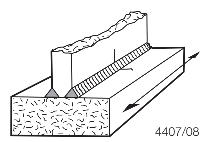
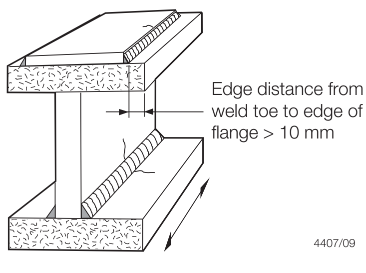
Type number, description and notes on mode of failure		Class explanatory comments	Examples, including failure modes
TYPE 1 MATERIAL FREE FROM WELDING Notes on potential modes of failure: In plain steel, fatigue cracks initiate at the surface, usually either at surface irregularities or at corners of the cross-section. In welded construction, fatigue failure will rarely occur in a region of plain material since the fatigue strength of the welded joints will usually be much lower. In steel with rivet or bolt holes or other stress concentrations arising from the shape of the member, failure will usually initiate at the stress concentration.			
1.1 Plain steel (a) In the as-rolled condition, or with cleaned surfaces but with no flame-cut edges of re-entrant corners.	B	Beware of using Class B for a member which may acquire stress concentration during its life, e.g. as a result of rust pitting. In such an event Class C would be more appropriate.	
(b) As (a) but with any flame-cut edges subsequently ground or machined to remove all visible sign of the drag lines.	B	Any re-entrant corners in flame-cut edges should have a radius greater than the plate thickness.	
(c) As (a) but with the edges machine flame-cut by a controlled procedure to ensure that the cut surface is free from cracks.	C	Note, however, that the presence of a re-entrant corner implies the existence of a stress concentration so that the design stress should be taken as the net stress multiplied by the relevant stress concentration factor.	
TYPE 2 CONTINUOUS WELDS ESSENTIALLY PARALLEL TO THE DIRECTION OF APPLIED STRESS Notes on potential modes of failure: With the excess weld metal dressed flush, fatigue cracks would be expected to initiate at weld defect locations. In the as-welded condition, cracks might initiate at stop-start positions or, if these are not present, at weld surface ripples. General comments: (a) Backing strips: If backing strips are used in making these joints: (i) they must be continuous; and (ii) if they are attached by welding those welds must also comply with the relevant Class requirements (note particularly that tack welds, unless subsequently ground out or covered by a continuous weld, would reduce the joint to Class F, *see* joint 6.5). (b) Edge distance: An edge distance criterion exists to limit the possibility of local stress concentrations occurring at unwelded edges as a result for example, of undercut, weld spatter or accidental overweave in manual fillet welding (*see also* notes on joint Type 4). Although an edge distance can be specified only for the 'width' direction of an element, it is equally important to ensure that no accidental undercutting occurs on the unwelded corners of, for example, cover plates or box girder flanges. If it does occur it should subsequently be ground smooth.			
2.1 Full or partial penetration butt welds, or fillet welds. Parent or weld metal in members, without attachments built up of plates or sections, and joined by continuous welds.			
(a) Full penetration butt welds with the weld overfill dressed flush with the surface and finish-machined in the direction of stress, and with the weld proved free from significant defects by non-destructive examination.	B	The significance of defects should be determined with the aid of specialist advice and/or by the use of fracture mechanics analysis. The NDT technique must be selected with a view to ensuring the detection of such significant defects.	
(b) Butt or fillet welds with the welds made by an automatic submerged or open arc process and with no stop-start positions within the length.	C	If an accidental stop-start occurs in a region where Class C is required remedial action should be taken so that the finished weld has a similar surface and root profile to that intended.	
(c) As (b) but with the weld containing stop-start positions within the length.	D	For situation at the ends of flange cover plates *see* joint Type 6.4.	

Table A3.1 Fatigue joint classification (*continued*)

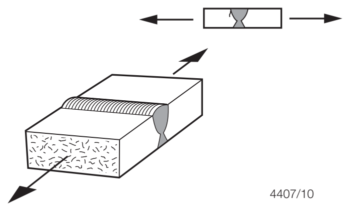
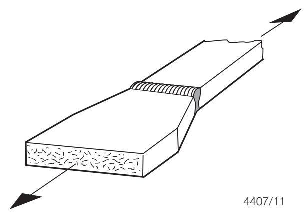
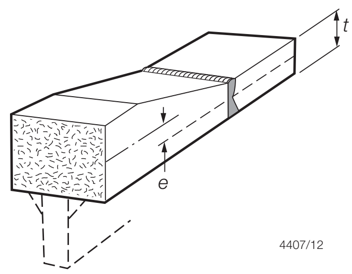
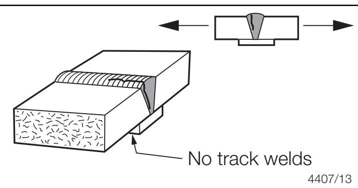
	Type number, description and notes on mode of failure		Class explanatory comments	Examples, including failure modes
TYPE 3	**TRANSVERSE BUTT WELDS IN PLATES** (i.e. essentially perpendicular to the direction of applied stress) Notes on potential modes of failure: With the weld ends machined flush with the plate edges, fatigue cracks in the as-welded condition normally initiate at the weld toe, so that the fatigue strength depends largely upon the shape of the weld overfill. If this is dressed flush the stress concentration caused by it is removed and failure is then associated with weld defects. In welds made on a permanent backing strip, fatigue cracks initiate at the weld metal/strip junction and in partial penetration welds (which should not be used under fatigue conditions), at the weld root. Welds made entirely from one side, without a permanent backing, require care to be taken in the making of the root bead in order to ensure a satisfactory profile. Design stresses: In the design of butt welds of Types 3.1 or 3.2 which are not aligned, the stresses must include the effect of any eccentricity. An approximate method of allowing for eccentricity in the thickness direction is to multiply the normal stress by $\left(1 + 3\frac{e}{t}\right)$, where *e* is the distance between centres of thickness of the two abutting members: if one of the members is tapered, the centre of the untapered thickness must be used; and *t* is the thickness of the thinner member. With connections which are supported laterally, e.g. flanges of a beam which are supported by the web, eccentricity may be neglected.			
3.1	Parent metal adjacent to or weld metal in full penetration butt joints welded from both sides between plates of equal width and thickness or where differences in width and thickness are machined to a smooth transition not steeper than 1 in 4.		Note that this includes butt welds which do not completely traverse the member, such as circular welds used for inserting infilling plates into temporary holes.	
(a)	With the weld overfill dressed flush with the surface and with the weld proved free from significant defects by non-destructive examination.	C	The significance of defects should be determine with the aid of specialist advice and/or by the use of fracture mechanic analysis. The NDT technique must be selected with a view to ensuring the detection of such significant defects.	
(b)	With the welds made, either manually or by an automatic process, other than submerged arc, provided all runs are made in the downhand position.	D	In general, welds made by the submerged arc process, or in positions other than downhand, tend to have a poor reinforcement shape, from the point of view of fatigue strength. Hence such welds are downgraded from D to E.	
(c)	Welds made other than in (a) or (b).	E	In both (b) and (c) of the corners of the cross-section of the stressed element at the weld toes should be dressed to a smooth profile. Note that step changes in thickness are in general, not permitted under fatigue conditions, but that where the thickness of the thicker member is not greater than 1,15 x the thickness of the thinner member, the change can be accommodated in the weld profile without any machining. Step changes in width lead to large reductions in strength (*see* joint Type 3.3).	
3.2	Parent metal adjacent to, or weld metal in, full penetration butt joints made on a permanent backing strip between plates of equal width and thickness or with differences in width and thickness machined to a smooth transition not steeper than 1 in 4.	F	Note that if the backing strip is fillet welded or tack welded to the member the joint could be reduced to Class G (joint Type 4.2).	

Table A3.1 Fatigue joint classification (*continued*)

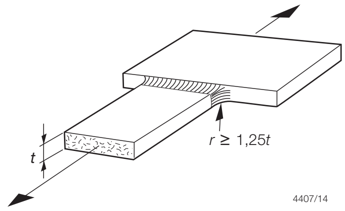
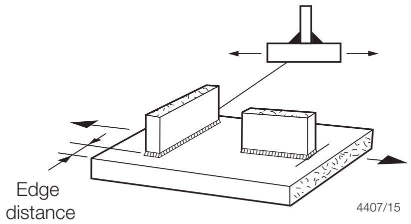
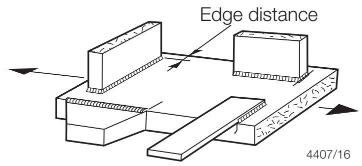
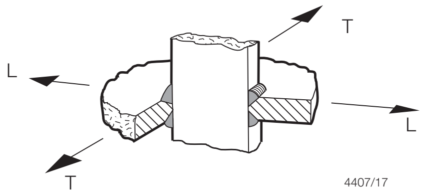
Type number, description and notes on mode of failure		Class explanatory comments	Examples, including failure modes
3.3 Parent metal adjacent to, or weld metal in, full penetration butt welded joints made from both sides between plates of unequal width, with the weld ends ground to a radius not less than 1,25 times the thickness *t*.	F2	Step changes in width can often be avoided by the use of shaped transition plates, arranged so as to enable butt welds to be made between plates of equal width. Note that for this detail the stress concentration has been taken into account in the joint classification.	
TYPE 4 WELDED ATTACHMENTS ON THE SURFACE OR EDGE OF A STRESSED MEMBER Notes on potential modes of failure: When the weld is parallel to the direction of the applied stress, fatigue cracks normally initiate at the weld ends, but when it is transverse to the direction of stressing they usually initiate at the weld toe; for attachments involving a single, as opposed to a double, weld cracks may also initiate at the weld root. The cracks then propagate into the stressed member. When the welds are on or adjacent to the edge of the stressed member the stress concentration is increased and the fatigue strength is reduced, this is the reason for specifying an 'edge distance' in some of these joints (*see also* note on edge distance in joint Type 2).			
4.1 Parent metal (of the stressed member) adjacent to toes or ends of bevel-butt or fillet welded attachments, regardless of the orientation of the weld to the direction of applied stress and whether or not the welds are continuous round the attachment.		Butt welded joints should be made with an additional reinforcing fillet so as to provide a similar toe profile to that which would exist in a fillet welded joint.	
(a) With attachment length (parallel to the direction of the applied stress) ≤ 150 mm and with edge distance ≥ 10 mm.	F	The decrease in fatigue strength with increasing attachment length is because more load is transferred into the longer gusset giving an increase in stress concentration.	
(b) With attachment length (parallel to the direction of the applied stress) > 150 mm and with edge distance ≤ 10 mm.	F2		
4.2 Parent metal (of the stressed member) at the toes or the ends of butt or fillet welded attachments on or within 10 mm of the edge or corners of a stressed member and regardless of the shape of the attachment.	G	Note that the classification applies to all sizes of attachment. It would therefore include, for example, the junction of two flanges at right angles. In such situations a low fatigue classification can often be avoided by the use of a transition plate (*see also* joint Type 3.3).	
4.3 Parent metal (of the stressed member) at the toe of a butt weld connecting the stressed member to another member slotted through it.		Note that this classification does not apply to fillet welded joints (*see* joint Type 5.1b). However it does apply to loading in either direction (L or T in the sketch).	
(a) With the length of the slotted-through member, parallel to the direction of the applied stress, ≤150 mm and with edge distance ≥10 mm.	F		
(b) With the length of the slotted-through member, parallel to the direction of the applied stress, >150 mm and with edge distance ≥10 mm.	F2		
(c) With edge distance <10 mm.	G		

Table A3.1 Fatigue joint classification (*continued*)

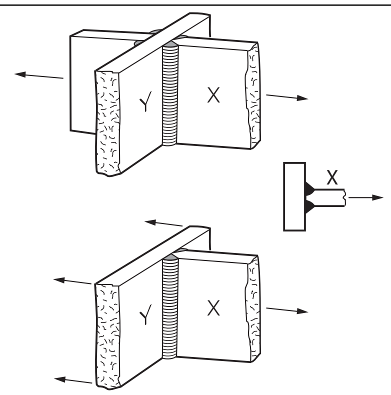
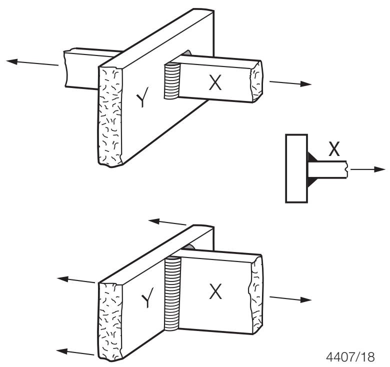
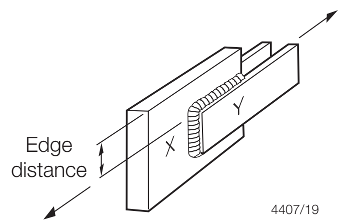
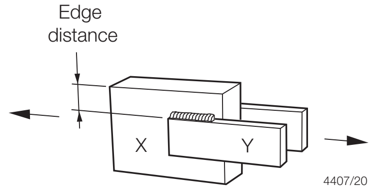
Type number, description and notes on mode of failure		Class explanatory comments	Examples, including failure modes
TYPE 5 LOAD-CARRYING FILLET AND T BUTT WELDS			
Notes on potential modes of failure:			
Failure in cruciform or T joints with full penetration welds will normally initiate at the weld toe, but in joints made with load-carrying fillet or partial penetration butt welds cracking may initiate either at the weld toe and propagate into the plate or at the weld root and propagate through the weld. In welds parallel to the direction of the applied stress, however, weld failure is uncommon, cracks normally initiate at the weld end and propagate into the plate perpendicular to the direction of applied stress. The stress concentration is increased, and the fatigue strength is therefore reduced, if the weld end is located on or adjacent to the edge of a stressed member rather than on its surface.			
5.1 Joint description Parent metal adjacent to cruciform joints or T joints (member marked X in sketches).		Member Y can be regarded as one with a non-load-carrying weld (*see* joint Type 4.1). Note that in this instance the edge distance limitation applies.	
(a) Joint made with full penetration welds and with any undercutting at the corners of the member dressed out by local grinding.	F		
(b) Joint made with partial penetration or fillet welds with any undercutting at the corners of the member dressed out by local grinding.	F2	In this type of joint, failure is likely to occur in the weld throat unless the weld is made sufficiently large (*see* joint Type 5.4).	
5.2 Parent metal adjacent to the toe of load-carrying fillet welds which are essentially transverse to the direction of applied stress (member X in sketch).		The relevant stress in member X should be calculated on the assumption that its effective width is the same as the width of member Y.	
(a) Edge distance ≥10 mm.	F2	These classifications also apply to joints with longitudinal weld only.	
(b) Edge distance <10 mm.	G		
5.3 Parent metal at the ends of load-carrying fillet welds which are essentially parallel to the direction of applied stress, with the weld end on plate edge (member Y in sketch).	G		
5.4 Weld metal in load-carrying joints made with fillet or partial penetration welds, with the welds either transverse or parallel to the direction of applied stress (based on nominal shear stress on the minimum weld throat area).	W	This includes joints in which a pulsating load may be carried in bearing, such as the connection of bearing stiffeners to flanges. In such examples the welds should be designed on the assumption that none of the load is carried in bearing.	

Table A3.1 **Fatigue joint classification** (*continued*)

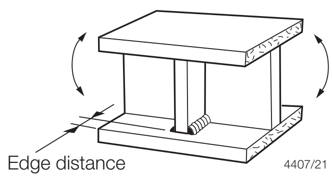
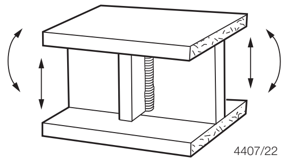
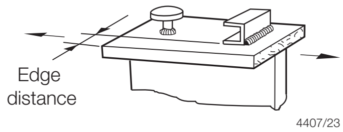
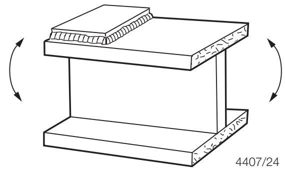
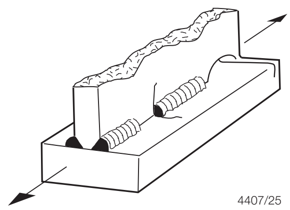
Type number, description and notes on mode of failure		Class explanatory comments	Examples, including failure modes
TYPE 6 DETAILS IN WELDED GIRDERS Notes on potential modes of failure: Fatigue cracks generally initiate at weld toes and are especially associated with local stress concentrations at weld ends, short lengths of return welds, and changes of direction. Concentrations are enhanced when these features occur at or near an edge of a part (*see* notes on joint Type 4). General comment: Most of the joints in this section are also shown, in a more general form in joint Type 4, they are included here for convenience as being the joints which occur most frequently in welded girders.			
6.1 Parent metal at the toe of a weld connecting a stiffener, diaphragm, etc., to a girder flange. (a) Edge distance ≥10 mm (*see* joint Type 4.2). (b) Edge distance <10 mm.	F G	Edge distance refers to distance from a free, i.e. unwelded edge. In this example, therefore, it is not relevant as far as the (welded) edge of the web plate is concerned. For reason for edge distance *see* note on joint Type 2.	
6.2 Parent metal at the end of a weld connecting a stiffener, diaphragm, etc., to a girder web in a region of combined bending and shear.	E	This classification includes all attachments to girder webs.	
6.3 Parent metal adjacent to welded shear connectors. (a) Edge distance ≥10 mm. (b) Edge distance <10 mm (*see* Type 4.2).	F G		
6.4 Parent metal at the end of a partial length welded cover plate, regardless of whether the plate has square or tapered ends and whether or not there are welds across the ends.	G	This Class includes cover plates which are wider than the flange. However, such a detail is not recommended because it will almost inevitably result in undercutting of the flange edge where the transverse weld crosses it, as well as involving a longitudinal weld terminating on the flange edge and causing a high stress concentration.	
6.5 Parent metal adjacent to the ends of discontinuous welds, e.g. intermittent web/flange welds, tack welds unless subsequently buried in continuous runs. Ditto, adjacent to cope holes.	E F	This also includes tack welds which are not subsequently buried in a continuous weld. This may be particularly relevant in tack welded backing strips. Note that the existence of the cope hole is allowed for in the joint classification, it should not be regarded as an additional stress concentration.	
TYPE 7 DETAILS RELATING TO TUBULAR MEMBERS			
7.1 Parent material adjacent to the toes of full penetration welded nodal joints.	T	In this situation design should be based on the hot spot stress as defined in Ch 5,5 (*see also* this Section for guidance on partial penetration welds).	

Table A3.1 Fatigue joint classification (*continued*)

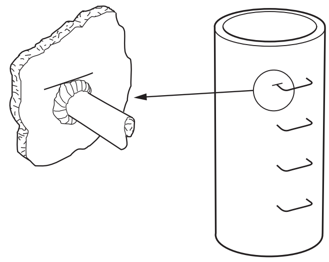
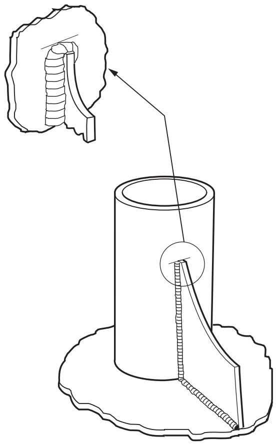
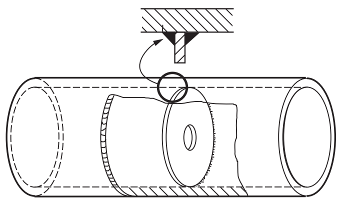
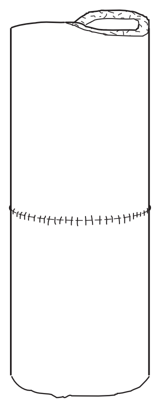
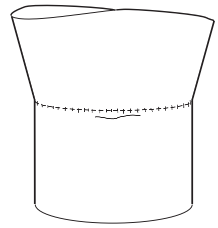
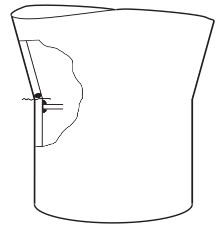
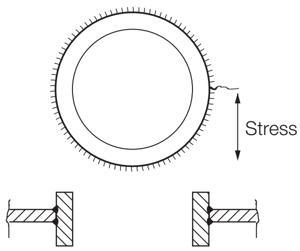
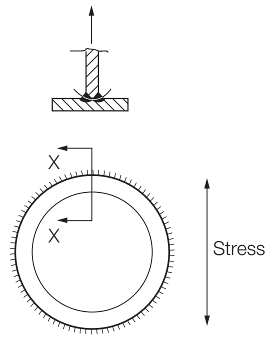
Type number, description and notes on mode of failure			Class explanatory comments	Examples, including failure modes
7.2	Parent metal at the toes of welds associated with small (≤150 mm in the direction parallel to the applied stress) attachments to the tubular member. As above, but with attachment length >150 mm.	F F2		 4407/26
7.3	Gusseted connections made with full penetration or fillet welds. (But note that full penetration welds are normally required).	F W	Note that the design stress must include any local bending stress adjacent to the weld end. For failure in the weld throat of fillet welded joints.	 4407/27
7.4	Parent material at the toe of a weld attaching a diaphragm or stiffener to a tubular member.	F	Stress should include the stress concentration factor due to overall shape of adjoining structure.	 4407/28
7.5	Parent material adjacent to the toes of circumferential butt welds between tubes.		In this type of joint the stress should include the stress concentration factor to allow for any thickness change and for fabrication tolerances.	 4407/29
(a)	Welds made from both sides with the weld overfill dressed flush with the surface and with the weld proved free from significant defects by non-destructive examination.	C	The significance of defects should be determined with the aid of specialist advice and/or by the use of fracture mechanics analysis. The NDT technique should be selected with a view to ensuring the detection of such significant defects.	
(b)	Weld made from both sides.	E		
(c)	Weld made from one side on a permanent backing strip.	F		
(d)	Weld made from one side without a backing strip provided that full penetration is achieved.	F2	Note that step changes in thickness are, in general, not permitted under fatigue conditions, but that where the thickness of the thicker member is not greater than 1,15 x the thickness of the thinner member, the change can be accommodated in the weld profile without any machining	

Table A3.1 Fatigue joint classification (*conclusion*)

Type number, description and notes on mode of failure		Class explanatory comments	Examples, including failure modes
7.6 Parent material at the toes of circumferential butt welds between tubular and conical section.	C E F F2	Class and stress should be those corresponding to the joint type as indicated in 7.5, but the stress must also include the stress concentration factor due to overall form of the joint.	
7.7 Parent material of the stressed member adjacent to the toes of bevel butt or fillet welded attachments in a region of stress concentration.	F or F2	Class depends on attachment length (*see* Type 4.1) but stress should include the stress concentration factor due to overall shape of adjoining structure.	
7.8 Parent metal adjacent to, or weld metal in, welds around a penetration through the wall of a member (on a plane essentially perpendicular to the direction of stress). Note that full penetration welds are normally required in this situation.	D	In this situation the relevant stress should include the stress concentration factor due to the overall geometry of the detail.	
7.9 Weld metal in partial penetration or fillet welded joints around a penetration through the wall of a member (on a plane essentially parallel to the direction of stress).	W	The stress in the weld should include an appropriate stress concentration factor to allow for the overall joint geometry.	

■ *Section A4* Stress concentration factors

A4.1 General

A4.1.1 In general, any discontinuity in a stressed structure results in a local increase in stress at the discontinuity. The ratio of the peak stress at the discontinuity to the nominal average stress that would prevail in the absence of the discontinuity is commonly referred to as the stress concentration factor (SCF). The peak stress (i.e. nominal stress x SCF) is normally used in conjunction with an appropriate S-N curve to derive the estimated fatigue life.

A4.1.2 The design weld S-N curves are given in Section A2 for the particular joint arrangements given in Section A3.

A4.1.3 Stress concentration factors may be derived using a number of different methods, such as finite element techniques, closed form analytical formula or from model tests. For complex arrangements, a detailed finite element based analysis will most likely be required.

A4.1.4 For semi-submersible units, experience has shown that the areas of minimum fatigue life are usually found at the joints, stiffener terminations, penetrations in primary bracings and also at their junctions with hull, columns and decks. For jack-up structures locations of minimum fatigue life are usually found on the lattice legs and support structure. Other structures subjected to significant cylic loading also require assessment.

A4.1.5 Stress concentration factors for tubular brace to chord connections may be determined from LR‘s technical report *Recommended Parametric Stress Concentration Factors* or an equivalent standard.

A4.1.6 Where finite element methods are used to determine local stress distributions for fatigue assessment, the geometric hot spot stress should account for the effect of structural discontinuities, excluding the presence of the weld. Misalignment of structural members should be accounted for where applicable.

A4.1.7 Linear extrapolation over reference points at 0,5 and 1,5 x plate thickness away from the point of interest (normally the weld toe) may be made to determine the geometric hot spot stress.

A4.1.8 In general, the geometric hot spot stress can be used in conjunction with the D class S-N curve given in Fig. A2.2.

A4.1.9 The maximum fabrication axial misalignment for fatigue prone locations would normally be limited to the smaller of 0,1 x t or 3 mm.

where

t = thickness of thinner plate

The maximum angular misalignment would be limited to the smaller of 0,001 x length of member or 3 mm. For this guidance, it may be assumed that the effects of these maximum fabrication misalignments are included within the S-N classification.

Rules and Regulations for the Classification of Mobile Offshore Units

Part 5
Main and Auxiliary Machinery

June 2013

LIFE MATTERS

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General Requirements for the Design and Construction of Machinery

Section

■ *Section 1* General

1.1 Machinery to be constructed under survey

1.1.1 In units built under Special Survey, all important units of equipment are to be surveyed at the manufacturer's works. The workmanship is to be to the Surveyor's satisfaction and the Surveyor is to be satisfied that the components are suitable for the intended purpose and duty. Examples of such units are:

- Main propulsion engines, including their associated gearing, flexible couplings, scavenge blowers and super-chargers.
- Boilers supplying steam for propulsion or for services essential for the safety or the operation of the unit at sea, including superheaters, economisers, desuper-heaters, steam heated steam generators and steam receivers. All other boilers having working pressures exceeding 3,4 bar (3,5 kgf/cm^2), and having heating surfaces greater than 4,65 m^2.
- Auxiliary engines which are the source of power for services essential for safety or for the operation of the unit at sea.
- Steering machinery.
- Thruster systems, their prime movers and control mechanisms.
- All pumps necessary for the operation of main propulsion and essential machinery, e.g., boiler feed, cooling water circulating, condensate extraction, oil fuel and lubricating oil pumps.
- All heat exchangers necessary for the operation of main propulsion and essential machinery, e.g., air, water and lubricating oil coolers, oil fuel and feed water heaters, de-aerators and condensers, evaporators and distiller units.
- Air compressors, air receivers and other pressure vessels necessary for the operation of main propulsion and essential machinery. Any other unfired pressure vessels for which plans are required to be submitted as detailed in Ch 11,1.6.
- All pumps essential for safety of the unit, e.g., fire, bilge and ballast pumps.
- Valves and other components intended for installation in pressure piping systems having working pressures exceeding 7 bar.
- Alarm and control equipment as detailed in Pt 6, Ch 1 and Pt 7, Ch 1.
- Electrical equipment and electrical propelling machinery as detailed in Pt 6, Ch 2.
- Drilling plant as detailed in Pt 3, Ch 7.
- Production and process plant as detailed in Pt 3, Ch 8.

1.2 Survey for classification

1.2.1 The Surveyors are to examine and test the materials and workmanship from the commencement of work until the final test of the machinery under full power working conditions. Any defects, etc., are to be indicated as early as possible. On completion, the Surveyors will submit a report and if this is found to be satisfactory by the Classification Committee, a certificate will be granted and an appropriate notation will be assigned in accordance with Pt 1, Ch 2.

1.3 Alternative system of inspection

1.3.1 Where items of machinery are manufactured as individual or series produced units, the Classification Committee will be prepared to give consideration to the adoption of a survey procedure based on quality assurance concepts, utilising regular and systematic audits of the approved manufacturing and quality control processes and procedures as an alternative to the direct survey of individual items.

1.3.2 In order to obtain approval, the requirements of Section 6 are to be complied with.

1.4 Departures from the Rules

1.4.1 Where it is proposed to depart from the requirements of the Rules, the Classification Committee will be prepared to give consideration to the circumstances of any special case.

1.4.2 Any novelty in the construction of the machinery, boilers or pressure vessels is to be reported to the Classification Committee.

■ *Section 2*
Plans and particulars

2.1 Plans

2.1.1 Before the work is commenced, plans in triplicate of all machinery items, as detailed in the Chapters giving the requirements for individual systems, are to be submitted for consideration. The particulars of the machinery, including machinery and equipment for elevating and lowering deck structure of self-elevating units and including power ratings and design calculations, where applicable, necessary to verify the design, are also to be submitted. Any subsequent modifications are subject to approval before being put into operation. It will not be necessary for plans and particulars to be submitted for each unit, provided the basis plans for the engine size and type have previously been approved as meeting the requirements of these Rules. Any alterations to basis design materials or manufacturing procedure are to be re-submitted for consideration.

2.2 Materials

2.2.1 The materials used in the construction are to be manufactured and tested in accordance with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials). Materials for which provision is not made therein may be accepted, provided that they comply with an approved specification and such tests as may be considered necessary.

2.2.2 Materials used in the construction of machinery and its installation are not to contain asbestos.

2.3 Welding

2.3.1 Welding consumables, plant and equipment are to be in accordance with the requirements specified in Ch 13,1.8 of the Rules for Materials.

2.3.2 Welding procedures and welder qualifications are to be tested and qualified in accordance with the requirements specified in Chapter 12 of the Rules for Materials.

2.3.3 Production weld tests are to be carried out where specified in the subsequent Chapters of these Rules.

2.3.4 All finished welds are to be subjected to non-destructive examination in accordance with the requirements specified in Ch 13,2.12 of the Rules for Materials and/or the requirements specified in the subsequent Chapters of these Rules.

■ *Section 3*
Operating conditions

3.1 Availability for operation

3.1.1 The design and arrangement are to be such that the machinery can be started and controlled on the unit, without external aid, so that the operating conditions can be maintained under all circumstances.

3.1.2 Machinery is to be capable of operating at defined power ratings with a range of fuel grades specified by the engine, boiler or machinery manufacturer and agreed by the Owner/Operator.

3.2 Fuel

3.2.1 The flash point (closed-cup test) of oil fuel for use on mobile offshore units is, in general, to be not less than 60°C.

3.2.2 For emergency generator engines, fuel having a flash point of not less than 43°C may be used.

3.2.3 Fuels with flash points lower than 60°C, but not less than 43°C unless specially approved, may be used in units in certain geographical areas where it can be ensured that the temperature of the machinery and boiler spaces will always be 10°C below the flash point of the fuel. In such cases, safety precautions and the arrangements for storage and pumping will be specially considered.

3.2.4 The use of fuel having a lower flash point than specified in 3.2.1 to 3.2.3 as applicable may be permitted provided that such fuel is not stored in any machinery space and the arrangements for the complete installation are specially approved.

3.2.5 For engines operating on 'boil-off' vapours from the cargo, *see* LR's *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquefied Gases in Bulk*.

3.3 Power ratings

3.3.1 In the Chapters where the dimensions of any particular component are determined from shaft power, P, in kW (H, in shp), and revolutions per minute, R, the values to be used are to be derived from the following:

- For main propelling machinery, the maximum shaft power and corresponding revolutions per minute giving the maximum torque for which the machinery is to be classed.
- For auxiliary machinery, the maximum continuous shaft power and corresponding revolutions per minute which will be used in service.

3.4 Definitions

3.4.1 Main propulsion engines and turbines are defined as those which drive main propelling machinery directly or indirectly through mechanical shafting and which may also drive electrical generators to provide power for auxiliary services. Auxiliary engines and turbines are defined as those coupled to electrical generators which provide power for auxiliary services, for electrical main propulsion motors or a combination of both.

3.4.2 Units and formulae included in the Rules are shown in SI units followed by metric units in brackets, where appropriate.

3.4.3 Where the metric version of shaft power, i.e., (shp), appears in the Rules, 1 shp is equivalent to 75 kgf m/s or 0,735 kW.

3.4.4 Pressure gauges may be calibrated in bar, where:

1 bar = 0,1 N/mm^2 = 1,02 kgf/cm^2.

3.5 Ambient reference conditions

3.5.1 The rating for classification purposes of main and essential auxiliary machinery intended for installation in units to be classed for unrestricted (geographical) service is to be based on a total barometric pressure of 1000 mb, an engine room ambient temperature or suction air temperature of 45°C, a relative humidity of 60 per cent and sea-water temperature or, where applicable, the temperature of the charge air coolant at the inlet of 32°C. The equipment manufacturer is not expected to provide simulated ambient reference conditions at a test bed.

3.6 Ambient operating conditions

3.6.1 Main and essential auxiliary machinery and equipment is to be capable of operating satisfactorily under the conditions shown in Table 1.3.1.

3.6.2 Where it is intended to allow for operation in ambient temperatures outside those shown in Table 1.3.1, the permissible temperatures and associated periods of time are to be specified and details are to be submitted for consideration. Propelling and essential auxiliary machinery, *see* Pt 1, Ch 2,2.8.1, is to retain a continuous level of functional capability under these conditions and any level of degraded performance is to be defined. Operation under these circumstances is not to be the cause of damage to equipment in the system and is additionally to be acceptable to the relevant Administration.

3.7 Inclination of unit

3.7.1 Main and essential auxiliary machinery is to operate satisfactorily under the conditions as shown in Table 1.3.2, Table 1.3.3 or Table 1.3.4.

Table 1.3.1 Ambient operating conditions

Air		
Installations, Components	Location, arrangement	Temperature range (°C)
Machinery and electrical installations	In enclosed spaces	0 to +45, *see* Note 1
	On machinery component, boilers. In spaces subject to higher and lower temperatures	According to specific local conditions, *see* Note 2
	On the open deck	–25 to +45, *see* Note 1
Water		
Coolant		Temperature (°C)
Sea-water or charge air coolant inlet to charge air cooler		–2 to +32, *see* Notes 1 and 3

NOTES
1. For units intended to be classed for restricted service, a deviation from the temperatures stated may be considered.
2. Details of local environmental conditions are stated in Annex B of IEC 60092: *Electrical installations in ships – Part 101: Definitions and general requirements.*
3. Charge air cooling arrangements utilising re-circulated cooling to maintain temperatures in a different range are accepted where the machinery and equipment operation is not degraded with a primary supply of cooling in the temperature range stated in this Table.

Table 1.3.2 Inclination of surface type units

Installations, components	Angle of inclination, degrees, *see* Note 1			
	Athwartships		Fore-and-aft	
	Static	Dynamic	Static	Dynamic
Main and auxiliary machinery essential to the propulsion and safety of the unit	15	22,5	5 *see* Note 2	7,5
Emergency machinery and equipment fitted in accordance with Statutory Requirements	22,5	22,5	10	10

NOTES
1. Athwartships and fore-and-aft inclinations may occur simultaneously.
2. Where the length of the unit exceeds 100 m, the fore-and-aft static angle of inclination may be taken as:

$$\frac{500}{L} \text{ degrees}$$

where
L = length of unit, in metres, *see* Pt 4, Ch 1,5.

3.7.2 Any proposal to deviate from the angles given in Table 1.3.2, Table 1.3.3 or Table 1.3.4 will be specially considered taking into account the type, size and service conditions of the unit.

Table 1.3.3 Inclination of column-stabilised units

Installations, components	Angle of inclination in any direction, degrees	
	Static	Dynamic
Main and auxiliary machinery essential to the propulsion and safety of the unit	15	22,5
Ballast system, emergency machinery and equipment fitted in accordance with statutory requirements	22,5	22,5

Table 1.3.4 Inclination of self-elevating units

Installations, components	Angle of inclination in any direction, degrees	
	Static	Dynamic
Main and auxiliary machinery and equipment essential to the propulsion and safety of the unit	10	15
Emergency machinery and equipment fitted in accordance with statutory requirements	15	15

3.7.3 The dynamic angles of inclination in Table 1.3.2, Table 1.3.3 or Table 1.3.4 may be exceeded in certain circumstances, dependent upon type of unit and operation. The Builder is, therefore, to ensure that the machinery is capable of operating under these angles of inclination.

3.8 Power conditions for generator sets

3.8.1 Auxiliary engines coupled to electrical generators are to be capable under service conditions of developing continuously the power to drive the generators at full rated output (kW) and, in the case of oil engines and gas turbines, of developing for a short period (15 minutes) an overload power of not less than 10 per cent, *see* Pt 6, Ch 2,9.2 of the Rules for Ships. In the case of oil engines, they are to be tested at works trials at an overload power of 10 per cent for a period of 30 minutes, *see* Table 2.18.1 in Chapter 2.

3.8.2 Engine builders are to satisfy the Surveyors by tests on individual engines that the above requirements, as applicable, can be complied with, due account being taken of the difference between the temperatures under test conditions and those referred to in 3.5. Alternatively, where it is not practicable to test the engine/generator set as a unit, type tests (e.g., against a brake) representing a particular size and range of engines may be accepted. With oil engines and gas turbines, any fuel stop fitted is to be set to permit the short period overload power of not less than 10 per cent above full rated output (kW) to be developed.

3.9 Astern power

3.9.1 Sufficient astern power is to be provided to maintain control of the unit in all normal circumstances.

3.9.2 Astern turbines are to be capable of maintaining in free route astern 70 per cent of the ahead revolutions, corresponding to the maximum propulsion shaft power for which the machinery is to be classed, for a period of at least 30 minutes without undue heating of the ahead turbines and condensers.

3.10 Machinery interlocks

3.10.1 Interlocks are to be provided to prevent any operation of engines or turbines under conditions that could hazard the machinery and personnel. These are to include ‘turning gear engaged’, ‘low lubricating oil pressure’, where oil pressure is essential for the prevention of damage during start up, ‘shaft brake engaged’ and where machinery is not available due to maintenance or repairs. The interlock system is to be arranged to be ‘fail safe’.

3.10.2 Where machinery is provided with manual turning gear, warning devices or notices may be provided as an alternative to interlocks as required by 3.10.1.

■ *Section 4*
Machinery room arrangements

4.1 Accessibility

4.1.1 Accessibility for attendance and maintenance purposes is to be provided for machinery plants.

4.2 Machinery fastenings

4.2.1 Bedplates, thrust seatings and other fastenings are to be of robust construction, and the machinery is to be securely fixed to the unit’s structure to the satisfaction of the Surveyor.

4.3 Resilient mountings

4.3.1 The dynamic angles of inclination in Table 1.3.2, Table 1.3.3 or Table 1.3.4 may be exceeded in certain circumstances dependent upon unit type and operation. The Builder is, therefore, to ensure that the vibration levels of flexible pipe connections, shaft couplings and mounts remain within the limits specified by the component manufacturer for the conditions of maximum dynamic inclinations to be expected during service, start-stop operation and the natural frequencies of the system. Due account is to be taken of any creep that may be inherent in the mount.

4.3.2 Anti-collision chocks are to be fitted together with positive means to ensure that manufacturers' limits are not exceeded. Suitable means are to be provided to accommodate the propeller thrust.

4.3.3 A plan showing the arrangement of the machinery together with documentary evidence of the foregoing is to be submitted.

4.4 Ventilation

4.4.1 All spaces including engine and cargo pump spaces, where flammable or toxic gases or vapours may accumulate, are to be provided with adequate ventilation under all conditions. *See also* Pt 7, Ch 2.

4.4.2 Machinery spaces shall be sufficiently ventilated so as to ensure that when machinery or boilers therein are operating at full power in all weather conditions, including heavy weather, a sufficient supply of air is maintained to the spaces for the operation of the machinery.

4.5 Fire protection

4.5.1 All surfaces of machinery where the surface temperature may exceed 220°C and where impingement of flammable liquids may occur are to be effectively shielded to prevent ignition. Where insulation covering these surfaces is oil-absorbing or may permit penetration of oil, the insulation is to be encased in steel or equivalent.

4.6 Means of escape

4.6.1 For means of escape from machinery spaces, *see* Pt 7, Ch 3.

4.7 Communications

4.7.1 Two independent means of communication are to be provided between the bridge and engine room control station from which the engines are normally controlled, *see also* Pt 6, Ch 1,2.

4.7.2 One of these means is to indicate visually the order and response, both at the engine room control station and on the bridge.

4.7.3 At least one means of communication is to be provided between the bridge and any other control position(s) from which the propulsion machinery may be controlled.

4.8 Category A machinery spaces

4.8.1 'Machinery spaces of Category A' are those spaces and trunks to such spaces which contain:

(a) internal combustion machinery used for main propulsion; or

(b) internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 kW; or

(c) any oil-fired boiler or oil fuel unit.

■ *Section 5* Trials

5.1 Inspection

5.1.1 Tests of components and trials of machinery, as detailed in the Chapters giving the requirements for individual systems, are to be carried out to the satisfaction of the Surveyors.

5.2 Sea trials

5.2.1 For all types of installation, the sea trials are to be of sufficient duration, and carried out under normal manoeuvring conditions, to prove the machinery under power. The trials are also to demonstrate that any vibration which may occur within the operating speed range is acceptable.

5.2.2 The trials are to include demonstrations of the following:

(a) The adequacy of the starting arrangements to provide the required number of starts of the main engines.

(b) The ability of the machinery to reverse the direction of thrust of the propeller in sufficient time, under normal manoeuvring conditions, and so bring the unit to rest from maximum service speed. Results of the trials are to be recorded.

(c) In turbine installations, the ability to permit astern running at 70 per cent of the full power ahead revolutions without adverse effects. This astern trial need only be of 15 minutes' duration, but may be extended to 30 minutes at the Surveyor's discretion.

5.2.3 Where controllable pitch propellers are fitted, the free route astern trial is to be carried out with the propeller blades set in the full pitch astern position. Where emergency manual pitch setting facilities are provided, their operation is to be demonstrated to the satisfaction of the Surveyors.

5.2.4 In geared installations, prior to full power sea trials, the gear teeth are to be suitably coated to demonstrate the contact markings, and on conclusion of the sea trials all gears are to be opened up sufficiently to permit the Surveyors to make an inspection of the teeth. The marking is to indicate freedom from hard bearing, particularly towards the ends of the teeth, including both ends of each helix where applicable. The contact is to be not less than that required by Ch 5,4.2 or Ch 5,5.2, as applicable.

5.2.5 The following information is to be available on board for the use of the Master and designated personnel:

- The results of trials to determine stopping times, unit headings and distance;
- For units having multiple propellers, the results of trials to determine the ability to navigate and manoeuvre with one or more propellers inoperative.
- For units having a single propulsor driven by multiple engines or electric motors, the results of trials to determine the ability to navigate and manoeuvre with the largest engine or electric motor inoperative.

5.2.6 Where the unit is provided with supplementary means for manoeuvring or stopping, the effectiveness of such means is to be demonstrated and recorded as referred to in 5.2.5.

5.2.7 The stopping distance achieved when the unit is initially proceeding ahead with a speed of at least 90 per cent of the unit's speed corresponding to 85 per cent of the maximum rated propulsion power, should not exceed 15 unit lengths after the astern order has been given. However, if the displacement of the unit makes this criterion impracticable then in no case should the stopping distance exceed 20 unit lengths.

5.2.8 All trials are to be to the Surveyor's satisfaction.

■ *Section 6* Quality Assurance Scheme for Machinery

6.1 General

6.1.1 This certification scheme is applicable to both individual and series produced items manufactured under closely controlled conditions and will be restricted to works where the employment of quality control procedures is well established. LR will have to be satisfied that the practices employed will ensure that the quality of finished products is to standards which would be demanded when using traditional survey techniques.

6.1.2 The Classification Committee will consider proposed designs for compliance with LR's Rules or other appropriate requirements and the extent to which the manufacturing processes and control procedure ensure conformity of the product to the design. A comprehensive survey will be made by the Surveyors of the actual operation of the quality control programme and of the adequacy and competence of the staff to implement it.

6.1.3 The procedures and practices of manufacturers which have been granted approval will be kept under review.

6.1.4 Approval by another organisation will not be accepted as sufficient evidence that a manufacturer's arrangements comply with LR's requirements.

6.2 Requirements for approval

6.2.1 **Facilities**. The manufacturer is required to have adequate equipment and facilities for those operations appropriate to the level of design, development and manufacture being undertaken.

6.2.2 **Experience**. The manufacturer is to demonstrate that the firm has experience consistent with technology and complexity of the product type for which approval is sought and that the firm's products have been of a consistently high standard.

6.2.3 **Quality policy**. The manufacturer is to define management policies and objectives or quality and ensure that these policies and objectives are implemented and maintained throughout all phases of the work.

6.2.4 **Quality system documentation**. The manufacturer is to establish and maintain a documented quality system capable of ensuring that material or services conform to the specified requirements, including the requirements of this Section.

6.2.5 **Management representative**. The manufacturer is to appoint a management representative, preferably independent of other functions, who is to have defined authority and responsibilities for the implementation and maintenance of the quality system.

6.2.6 **Responsibility and authority**. The responsibilities and authorities of senior personnel within the quality system are to be clearly documented.

6.2.7 **Internal audit**. The manufacturer is to conduct internal audits to ensure continued adherence to the system. An audit programme is to be established with audit frequencies scheduled on the basis of the status and importance of the activity and adjusted on the basis of previous results.

6.2.8 **Management review**. The quality system established in accordance with the requirements of this Section is to be systematically reviewed at appropriate intervals by the manufacturer to ensure its continued effectiveness. Records of such management reviews are to be maintained and be made available to the Surveyors.

6.2.9 **Contract review**. The manufacturer is to establish and implement procedures for conducting a contract review prior to and after acceptance to ensure that:

(a) the requirements of the contract are adequately defined and documented;
(b) any requirements differing from those specified in the original enquiry/tender are resolved; and
(c) the manufacturer has the capability to meet and verify compliance to the specified requirements.

6.2.10 **Work instruction**. The manufacturer is to establish and maintain clear and complete written work instructions that prescribe the communication of specified requirements and the performance of work in design, development and manufacture which would be adversely affected by lack of such instructions.

6.2.11 **Documentation and change control**. The manufacturer is to establish and maintain control of all documentation that relates to the requirements of this scheme. This control is to ensure that:

(a) documents are reviewed and approved for adequacy by authorised personnel prior to use, are uniquely identified and include indication of approval and revision status;
(b) all changes to documentation are in writing and are processed in a manner that will ensure their availability at the appropriate location and preclude the use of non-applicable documents;
(c) provision is made for the prompt removal of obsolete documentation from all points of issue or use; and
(d) documents are to be re-issued after a practical number of changes have been issued.

6.2.12 **Records**. The manufacturer is to develop and maintain a system for collection, use and storage of quality records. The period of retention of such records is to be established in writing and is to be subject to agreement by the Classification Committee.

6.2.13 **Design**. The manufacturer is to establish and maintain a design control system appropriate to the level of design being undertaken. Documented design procedures are to be established which:

(a) identify the design practices of the manufacturer's organisation including departmental instructions to ensure the orderly and controlled preparation of design and subsequent verification;
(b) make provision for the identification, documentation and appropriate approval of all design change and modifications;
(c) prescribe methods for resolving incomplete, ambiguous or conflicting requirements; and
(d) identify design inputs such as sources of data, preferred standard parts or materials and design information and provide procedures for their selection and review by the manufacturer for adequacy.

6.2.14 **Purchasing**. The manufacturer is to ensure that purchased material and services conform to specified requirements.

6.2.15 **Selection and approval of sub-contractors and suppliers**. The manufacturer is to establish and maintain records of acceptable suppliers and sub-contractors. The selection of such sources, and the type and extent of control exercised, are to be appropriate to the type of product or service and the suppliers' or sub-contractors' previously demonstrated capability and performance. Documented procedures for approval of new suppliers are to be established and records of vendor assessments (where carried out) are to be maintained and made available to the Surveyors upon request.

6.2.16 **Purchasing data**. Each purchasing document should contain a clear description of the material or service ordered, including, as applicable, the following:

(a) The type, class, grade, or other precise identification;
(b) The title or other positive identification and applicable issue of specifications, drawings, process requirements, inspection instructions and other relevant data.

6.2.17 **Verification of purchased material and services**. The manufacturer is to ensure that the Surveyors are afforded the right to verify at source or upon receipt that purchased material and services conform to specified requirements. Verification by the Surveyors shall not relieve the manufacturer of his responsibility to provide acceptable material nor is it to preclude subsequent rejection.

6.2.18 **Product identification**. The manufacturer is to establish and maintain a system for identification of the product to relevant drawings, specifications or other documents during all stages of production, delivery and installation.

6.2.19 **Manufacturing control**. The manufacturer is to ensure that those operations which directly affect quality are carried out under controlled conditions. These are to include the following:

(a) Written work instructions wherever the absence of such instructions could adversely affect compliance with specified requirements. These should define the method of monitoring and control of product characteristics.
(b) Established criteria for workmanship through written standards or representative samples.

6.2.20 **Special processes**. Those processes where effectiveness cannot be verified by subsequent inspection and test of the product are to be subjected to continuous monitoring in accordance with documented procedures, in addition to the requirements specified in 6.2.19.

6.2.21 **Receiving inspection**. The manufacturer is to ensure that all incoming material is not to be used or processed until it has been inspected or otherwise verified as conforming to specified requirements. In establishing the amount and nature of receiving inspection, consideration is to be given to the control exercised by the supplier and documented evidence of quality conformance supplied.

6.2.22 **In-process inspection**. The manufacturer is to:

(a) perform inspection during manufacture on all characteristics that cannot be inspected at a later stage;
(b) inspect, test and identify products in accordance with specified requirements;
(c) establish product conformance to specified requirements by use of process monitoring and control methods where appropriate;
(d) hold products until the required inspections and tests are completed and verified; and
(e) clearly identify non-conforming products to prevent unauthorised use, shipment, or mixing with conforming material.

6.2.23 **Final inspection**. The manufacturer is to perform all inspections and tests on the finished product necessary to complete the evidence of conformance to the specified requirements. The procedures for final inspection and test are to ensure that:

(a) all activities defined in the specification, quality plan or other documented procedure have been completed;
(b) all inspections and tests that should have been conducted at earlier stages have been completed and that the data is acceptable; and
(c) no product is to be dispatched until all the activities defined in the specifications, quality plan or other documented procedure have been completed, unless products have been released with the permission of the Surveyors.

6.2.24 **Inspection equipment.** The manufacturer is to be responsible for providing, controlling, calibrating and maintaining the inspection, measuring and test equipment necessary to demonstrate the conformance of material and services to the specified requirements or used as part of the manufacturing control system required by 6.2.19 and 6.2.20.

6.2.25 **Inspection and test status**. The manufacturer is to establish and maintain a system for the identification of inspection status of all material, components and assemblies by suitable means which distinguish between conforming, non-conforming and uninspected items. The relevant inspection and test procedures and records are to identify the authority responsible for the release of conforming products.

6.2.26 **Control of non-conforming material**.

(a) The manufacturer is to establish and maintain procedures to ensure that material that does not conform to the specified requirements is controlled to prevent inadvertent use, mixing or shipment. Repair, rework or concessions on non-conforming material and re-inspection are to be in accordance with documented procedures.
(b) Records clearly identifying the material, the nature and extent of non-conformance and the disposition are to be maintained.

6.2.27 **Sampling procedures**. Where sampling techniques are used by the manufacturer to verify the acceptability of groups of products, the procedures adopted are to be in accordance with the specified requirements or are to be subject to agreement by the Surveyors.

6.2.28 **Corrective action**. The manufacturer is to establish and maintain documented procedures for the review of non-conformances and their disposition. These should provide for:

(a) monitoring of process and work operations and analysis of records to detect and eliminate potential causes of non-conforming material;
(b) continuing analysis of concessions granted and material scrapped or reworked to determine causes and the corrective action required;
(c) an analysis of customer complaints;
(d) the initiation of appropriate action with suppliers or sub-contractors with regard to receipt of non-conforming material; and
(e) an assurance that corrective actions are effective.

6.2.29 **Purchaser supplied material**. The manufacturer is to establish and maintain documented procedures for the control of purchaser supplied material.

6.2.30 **Handling, storage, and delivery**:

(a) The manufacturer is to establish and maintain a system for the identification preservation, segregation and handling of all material from the time of receipt through the entire production process. The system is to include methods of handling that prevent abuse, misuse, damage or deterioration.
(b) Secure storage areas or rooms are to be provided to isolate and protect material pending use. To detect deterioration at an early stage, the condition of material is to be periodically assessed.
(c) The manufacturer is to arrange for the protection of the quality of his product during transit. The manufacturer is to ensure, in so far as it is practicable, the safe arrival and ready identification of the product at destination.

6.2.31 **Training**. The manufacturer is to follow a policy for recruitment and training which provides an adequate labour force with such skills as are required for each type of work operation. Appropriate records are to be maintained to demonstrate that all personnel performing process control, special processes inspection and test or quality system maintenance activities have appropriate experience or training.

6.3 Arrangements for acceptance and certification of purchased material

6.3.1 The manufacturer is to establish and maintain procedures and controls to ensure compliance with LR's requirements for certification of materials and components at the supplier's plant. The manufacturer's system for control of such purchased material may be based on one of the following alternatives, subject to the approval of LR:

(a) Product certification by LR's Surveyors at the supplier's works in accordance with the requirements of the Rules for Materials.
(b) Agreed Inspection Procedures at the manufacturer's plant combined with documentary evidence of vendor assessments, vendor rating records and annual surveillance visits to the suppliers.
(c) Recognition of quality agreements between the manufacturer and his suppliers which are to provide for initial vendor assessments and regular surveillance visits (a minimum of four per year). The quality agreement must identify the individual in the supplier's plant who is charged with the responsibility for release of materials or components and the procedures to be adopted.

6.3.2 The alternatives proposed in 6.3.1(b) and (c) are not acceptable to LR for the following items:

(a) Engine components for which testing is a Rule requirement; and
    (i) the cylinder bore is equal to or exceeds 300 mm; or
    (ii) which are made by open forging techniques.
(b) Cast crankshafts where the journal diameter exceeds 85 mm.

6.3.3 Where the manufacturer's system for control of purchased material is based upon 6.3.1(b) or (c), the Surveyors shall also make surveillance visits to the supplier's works at the minimum specified intervals. The manufacturer is also to make available to the Surveyors documentary evidence of the operation of quality agreements or Agreed Inspection Procedures where applicable.

6.4 Information required for approval

6.4.1 Manufacturers applying for approval under this scheme are to submit the following information:

(a) A description of the products for which certification is required including, where applicable, model or type number.
(b) Applicable plans and details of material used.
(c) An outline description of all important manufacturing plant and equipment.
(d) A summary of equipment used for measuring and testing during manufacture and completion.
(e) The Quality Manual.
(f) A typical production flow chart and quality plan covering all stages from ordering of materials to delivery of the finished product.
(g) The system used for the identification of raw materials, semi-finished and finished products.
(h) The number and qualifications of all staff engaged in testing, inspection and quality control duties.
(j) A list of suppliers of components and manufacturers, proposed procedures to ensure compliance with LR's requirements for certification of materials and components at the supplier's plant.

6.5 Assessment of works

6.5.1 After receipt and appraisal of the information requested in 6.4, an inspection of the works is to be carried out by the Surveyors to examine in detail all aspects of production, and in particular the arrangements for quality control.

6.5.2 The Surveyors will not specify in detail acceptable quality control procedures, but will consider the arrangements proposed by the works in relation to the manufacturing processes and products.

6.5.3 In the event of procedures being considered inadequate, the Surveyors will advise the manufacturer how such procedures are to be revised in order to be acceptable to LR.

6.5.4 Gauging, measuring and testing devices are to be made available to the Surveyors, and where appropriate, personnel for the operation of such devices.

6.6 Approval of works

6.6.1 If the initial assessment of the works confirms that the manufacturing and quality control procedures are satisfactory, the Classification Committee will issue to the manufacturer a Quality Assurance Approval Certificate which will include details of the products for which approval has been given. This Certificate will be valid for three years with renewal subject to satisfactory performance and to a satisfactory triennial reassessment.

6.6.2 An extension of approval in respect of product type may be given at the discretion of the Classification Committee without any additional survey of the works.

6.6.3 LR will publish a list of manufacturers whose works have been approved.

6.7 Maintenance of approval

6.7.1 The arrangements authorised at each works are to be kept under review by the Surveyors in order to ensure that the approved procedures for manufacture and quality control are being maintained in a satisfactory manner. This is to be carried out by:

(a) regular and systematic surveillance;
(b) intermediate audits at intervals of six months;
(c) triennial reassessment of the entire quality system.

6.7.2 For the purpose of regular and systematic surveillance, the Surveyors are to visit the works at intervals determined by the type of product and the rate of production. The Surveyors are to advise a senior member of the quality control department in regard to any matter with which they are not satisfied.

6.7.3 When minor deficiencies in the approved procedures are disclosed during the systematic surveillance the Surveyors may, at their discretion, apply more intensive supervision, including the direct inspection of products.

6.7.4 Any noteworthy departures from the approved plans of specifications are to be reported to the Surveyors and their written approval obtained prior to despatch of the item.

6.7.5 Minor alterations in the approved procedures may be permitted provided that the Surveyors are advised and their prior concurrence obtained.

6.7.6 In addition to the regular visits by the Surveyors, an intermediate audit is to be carried out every six months. This will normally be carried out by Surveyors other than those regularly in attendance at the works. This audit is to consist of an examination of part of the manufacturer's quality system. An audit plan will be established indicating those areas of the quality system which will be examined during every intermediate audit and the frequency of examination of other areas such that all areas are subject to audit before reassessment is due.

6.7.7 The manufacturer's entire quality system is to be subject to reassessment at three-yearly intervals. This is to be conducted by Surveyors nominated by LR.

6.8 Suspension or withdrawal of approval

6.8.1 When the Surveyors have drawn attention to significant faults or deficiencies in the manufacturing or quality control procedures and these have not been rectified, approval of the works will be suspended. In these circumstances, the manufacturer will be notified in writing of the Classification Committee's reasons for the suspension of approval.

6.8.2 When approval has been suspended and the manufacturer does not effect corrective measures within a reasonable time, the Classification Committee will withdraw the Quality Assurance Approval Certificate.

6.9 Identification of products

6.9.1 In addition to the normal marking by the manufacturer, all certified products are to be hard stamped on a principal component with a suitable identification, LR's brand and the number of the approved works.

6.9.2 After issue of the Quality Assurance Approval Certificate, products may be dispatched with certificates signed on behalf of the manufacturer by an authorised senior member of the quality control department or by an authorised deputy. These certificates are to be countersigned by the Surveyor to certify that the approved arrangements are being kept under review by regular and systematic auditing of the manufacturer's quality system.

6.9.3 The following declarations are to be included on each certificate:

(a) 'This is to certify that the items described above have been constructed and tested with satisfactory results in accordance with the Rules of Lloyd's Register.
Signed..
Manager of QC Department.'

(b) 'This certificate is issued by the manufacturer in accordance with the arrangements authorised by Lloyd's Register in Quality Assurance Approval Certificate No. QA.M.................................. I certify that these arrangements are being kept under review by regular and systematic auditing of the approved manufacturing and quality control procedures.
Signed..
Surveyor to Lloyd's Register'.

6.9.4 In the event of noteworthy departures from the approved plan or specification being accepted, a standard 'Concession' form is to be completed and signed by the following authorised persons: the design Manager, the Quality Control Manager or their deputies. In all cases, where strength or functioning may be affected, the form is to be submitted to the Surveyors for approval and endorsement.

■ *Section 7* Spare gear for machinery installations

7.1 Application

7.1.1 Adequate spare parts for the propelling and essential auxiliary machinery, together with the necessary tools for maintenance and repair, are to be readily available for use.

7.1.2 The spare parts to be supplied and their location is to be the responsibility of the Owner, but they must take into account the design and arrangement of the machinery and the intended service and operation of the unit. Account must also be taken of the recommendations of the manufacturers and any applicable requirement of the relevant Administration.

7.2 Guidance for spare parts

7.2.1 For general guidance purposes, spare parts for main and auxiliary machinery installations are shown in the LR's *Spare Gear Guidance* located on Class Direct Live.

Scope

The requirements of this Chapter are applicable to oil engines (generally known as diesel engines) for main propulsion and to engines intended for essential auxiliary services. Section 3 is not applicable to auxiliary engines having powers of less than 110 kW.

The requirements for type testing of engines at the manufacturer's works are also included.

Arrangements for dual fuel engines will be specially considered.

Section 1
Plans and particulars

1.1 Plans

1.1.1 The following plans and particulars as applicable are to be submitted for consideration:

- Crankshaft assembly plan (for each crankthrow).
- Crankshaft details plan (for each crankthrow).
- Thrust shaft or intermediate shaft (if integral with engine).
- Output shaft coupling bolts.
- Main engine securing arrangements where non-metallic chocks are used.
- Type and arrangement of crankcase explosion relief valves.
- Arrangement and welding specifications with details of the procedures for fabricated bedplate, thrust bearing bedplate, crankcases, frames and entablatures. Details of materials, welding consumables, fit-up conditions, fabrication sequence and heat treatments are to be included.
- Schematic layouts of the following systems:
  - Starting air.
  - Oil fuel.
  - Lubricating oil.
  - Cooling water.
  - Control and safety.
  - Hydraulic oil (for valve lift).
- Shielding of high pressure fuel pipes.
- Combustion pressure-displacement relationship.
- Crankshaft design data as outlined in Section 3.
- High pressure parts for fuel oil injection system with specification of pressures, pipe dimensions and materials.
- For new engine types that have not been approved by LR, the proposed type test programme.
- The type test report on completion of type testing for a new engine type. For mass produced engines, a separate report is to be submitted for each engine requiring approval, *see* 11.5.
- Additionally, for mass produced engines:
  - (a) For consideration of an engine type to be approved:
    - (i) Engine specification, *see* 11.1.4.
    - (ii) Manufacturing processes and quality control information, *see* 11.2.3.
    - (iii) List of sub-contractors for main parts.
    - (iv) Procedures for configuring during commissioning.
  - (b) For engines of an approved type to be installed on a unit, a compliance and inspection certificate, *see* 11.4.
- For engine control, alarm monitoring and safety systems, the plans and information required by Pt 6, Ch 1,1.2.
- For electronically controlled engines, the plans and information required by 15.2.
- Schematic layouts showing details and arrangements of oil mist detection/monitoring and alarm systems.

1.1.2 The following plans are to be submitted for information:

- Longitudinal and transverse cross-section.
- Cast bedplate, thrust bearing bedplate, crankcase and frames.
- Cylinder head assembly.
- Cylinder liner.
- Piston assembly.
- Tie rod.
- Connecting rod, piston rod, and crosshead assemblies.
- Camshaft drive and camshaft general arrangement.
- Shielding and insulation of exhaust pipes.
- Details of turbochargers, *see* Section 10.
- Operation and service manuals.
- Vibration dampers/detuners and moment compensators.
- Thrust bearing assembly (if integral with engine and not integrated in the bedplate).
- Counterweights, where attached to crankthrow, including fastening.
- Main engine holding-down arrangement (metal chocks).

1.1.3 Material specifications covering the listed components in 1.1.1 and 1.1.2 are to be forwarded together with details of any surface treatments, non-destructive testing and hydraulic tests.

1.1.4 Plans and details for dead ship condition starting arrangements are to be submitted for appraisal, *see* 8.11.

1.1.5 For engine types built under license it is intended that the above documentation be submitted by the Licensor. Each Licensee is then to submit the following:

- A list, based on the above, of all documents required with the relevant drawing numbers and revision status from both Licensor and Licensee.
- The associated documents where the Licensee proposes design modifications to components. In such cases, a statement is to be made confirming the Licensor's acceptance of the proposed changes. In all cases, a complete set of endorsed documents will be required by the Surveyor(s) attending the Licensee's works.

1.1.6 Where considered necessary LR may require additional documentation to be submitted.

■ *Section 2* Materials

2.1 Crankshaft materials

2.1.1 The specified minimum tensile strength of castings and forgings for crankshafts is to be selected within the following general limits:

(a) Carbon and carbon-manganese steel castings – 400 to 550 N/mm^2.
(b) Carbon and carbon-manganese steel forgings (normalised and tempered) – 400 to 600 N/mm^2.
(c) Carbon and carbon-manganese steel forgings (quenched and tempered) – not exceeding 700 N/mm^2.
(d) Alloy steel castings – not exceeding 700 N/mm^2.
(e) Alloy steel forgings – not exceeding 1000 N/mm^2.
(f) Spheroidal or nodular graphite iron castings – 370 to 800 N/mm^2.

2.1.2 Where it is proposed to use alloy castings, micro alloyed or alloy steel forgings or iron castings, details of the chemical composition, heat treatment and mechanical properties are to be submitted for approval.

2.2 Material test and inspections

2.2.1 Components for engines are to be tested as indicated in Table 2.2.1 and in accordance with the relevant requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

2.2.2 For components of novel design, special consideration will be given to the material test and non-destructive testing requirements.

■ *Section 3* Design

3.1 Scope

3.1.1 The formulae given in this Section are applicable to solid, or semi-built crankshafts, having a main support bearing adjacent to each crankpin, and are intended to be applied to a single crankthrow analysed by the static determinate method.

3.1.2 Alternative methods, including a fully documented stress analysis, will be specially considered.

3.1.3 Calculations are to be carried out for the maximum continuous power rating for all intended operating conditions.

3.1.4 Designs of crankshafts not included in this scope will be subject to special consideration.

3.2 Information to be submitted

3.2.1 In addition to detailed dimensioned plans, the following information is required to be submitted:

- Engine type – 4SCSA/2SCSA/in-line/vee.
- Output power at maximum continuous rating (MCR), in kW.
- Output speed at maximum continuous power, in rpm.
- Maximum cylinder pressure, in bar g.
- Mean indicated pressure, in bar g.
- Cylinder air inlet pressure, in bar g.
- Digitised gas pressure/crank angle cycle for MCR.
- Maximum pressure/speed relationship.
- Compression ratio.
- Vee angle and firing interval (if applicable), in degrees.

Table 2.2.1 Test requirements for oil engine components

Component	Material tests	Non-destructive tests: Magnetic particle or Liquid penetrant	Non-destructive tests: Ultrasonic
Crankshaft	all	all	all
Crankshaft coupling flange (non-integral) for main propulsion engines	above 400 mm bore	—	—
Crankshaft coupling bolts	above 400 mm bore	—	—
Steel piston crowns	above 400 mm bore	above 400 mm bore	all
Piston rods	above 400 mm bore	above 400 mm bore	above 400 mm bore
Connecting rods, including bearing caps	all	all	above 400 mm bore
Crosshead	above 400 mm bore	—	—
Cylinder liner	above 300 mm bore	—	—
Cylinder cover	above 300 mm bore	above 400 mm bore	all
Steel castings for welded bedplates	all	all	all
Steel forgings for welded bedplates	all	—	—
Plates for welded bedplates, frames and entablatures	all	—	—
Crankcases, welded or cast	all	—	—
Tie rods	all	above 400 mm bore	—
Turbo-charger, shaft and rotor	above 300 mm bore	—	—
Bolts and studs for cylinder covers, crossheads, main bearings, connecting rod bearings	above 300 mm bore	above 400 mm bore	—
Steel gear wheels for camshaft drives	above 400 mm bore	above 400 mm bore	—

NOTES
1. For closed-die forged crankshafts the ultrasonic examination may be confined to the initial production and to subsequent occasional checks.
2. Magnetic particle or liquid penetrant testing of tie rods may be confined to the threaded portions and the adjacent material over a length equal to that of the thread.
3. Cylinder covers and liners manufactured from spheroidal or nodular graphite iron castings may not be suitable for ultrasonic NDE, depending upon the grain size and geometry. An alternative NDE procedure is to be agreed with LR.
4. Bore dimensions refer to engine cylinder bores.
5. All required material tests are to be witnessed by the Surveyor unless alternative arrangements have been specifically agreed by LR.
6. For mass produced engines, *see* Section 11.

- Firing order numbered from driving end, *see* Fig. 2.3.1.
- Cylinder diameter, in mm.
- Piston stroke, in mm.
- Mass of connecting rod (including bearings), in kg.
- Centre of gravity of connecting rod from large end centre, in mm.
- Radius of gyration of connecting rod, in mm.
- Length of connecting rod between bearing centres, in mm.
- Mass of single crankweb (indicate if webs either side of pin are of different mass values), in kg.
- Centre of gravity of crankweb mass from shaft axis, in mm.
- Mass of counterweights fitted (for complete crankshaft) indicate positions fitted, in kg.
- Centre of gravity of counterweights (for complete crankshaft) measured from shaft axis, in mm.
- Mass of piston (including piston rod and crosshead where applicable), in kg.
- All individual reciprocating masses acting on one crank, in kg.
- Material specification(s).
- Specified minimum UTS, in N/mm^2.
- Specified minimum yield strength, in N/mm^2.
- Method of manufacture.
- Details of fatigue enhancement process (if applicable).
- For semi-built crankshafts – minimum and maximum diametral interference, in mm.

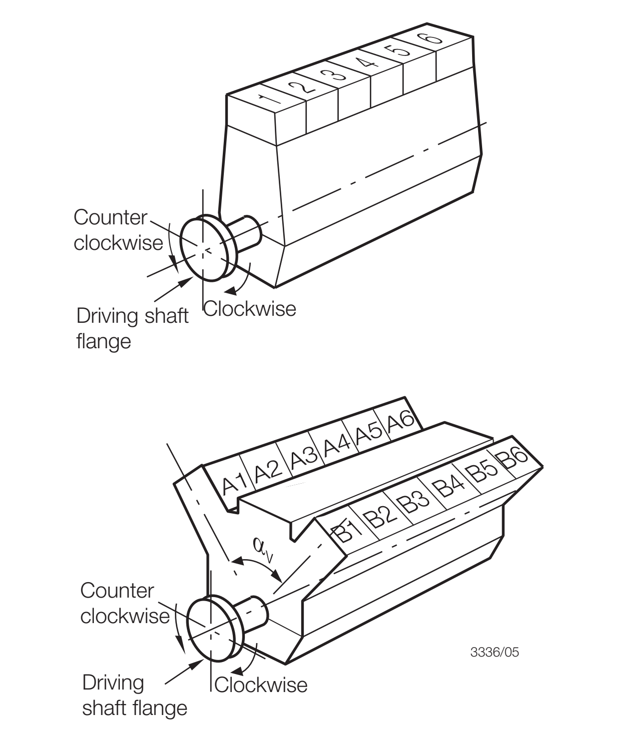


Fig. 2.3.1 Designation of cylinders

3.3 Symbols

3.3.1 For the purposes of this Chapter the following symbols apply, *see also* Fig. 2.3.2:

h = radial thickness of web, in mm
k_e = bending stress factor
B = transverse breadth of web, in mm
D_p, D_j = outside diameter of pin or main journal, in mm
D_{pi}, D_{ji} = internal diameter of pin or main journal, in mm
D_s = shrink diameter of main journal in web, in mm
d_o = diameter of radial oil bore in crankpin, in mm
F = alternating force at the web centreline, in N
K_1 = fatigue enhancement factor due to manufacturing process
K_2 = fatigue enhancement factor due to surface treatment
M_b = alternating bending moment at web centreline, in N-mm
(NOTE: alternating is taken to be 1/2 range value)
M_{BON} = alternating bending moment calculated at the outlet of crankpin oil bore
M_p, M_j = undercut of fillet radius into web measured from web face, in mm
R_p, R_j = fillet radius at junction of web and pin or journal, in mm
S = stroke, in mm
T = axial thickness of web, in mm
T_a = alternating torsional moment at crankpin or crank journal, in N-mm (NOTE: alternating is taken to be 1/2 range value).
U = pin overlap

$$= \frac{(D_p + D_j - S)}{2} \text{ mm}$$

α_B = bending stress concentration factor for crankpin
α_T = torsional stress concentration factor for crankpin
β_B = bending stress concentration factor for main journal
β_Q = direct shear stress concentration factor for main journal
β_T = torsional stress concentration factor for main journal
γ_B = bending stress concentration factor for radially drilled oil hole in the crankpin
γ_T = torsional stress concentration factor for radially drilled oil hole in the crankpin
σ_{ax} = alternating axial stress, in N/mm^2
σ_b = alternating bending stress, in N/mm^2
σ_{BON} = alternating bending stress in the outlet of the oil bore, in N/mm^2
σ_p, σ_j = maximum bending stress in pin and main journal, taking into account stress raisers, in N/mm^2
σ_{BO} = maximum bending stress in the outlet of the oil bore, in N/mm^2

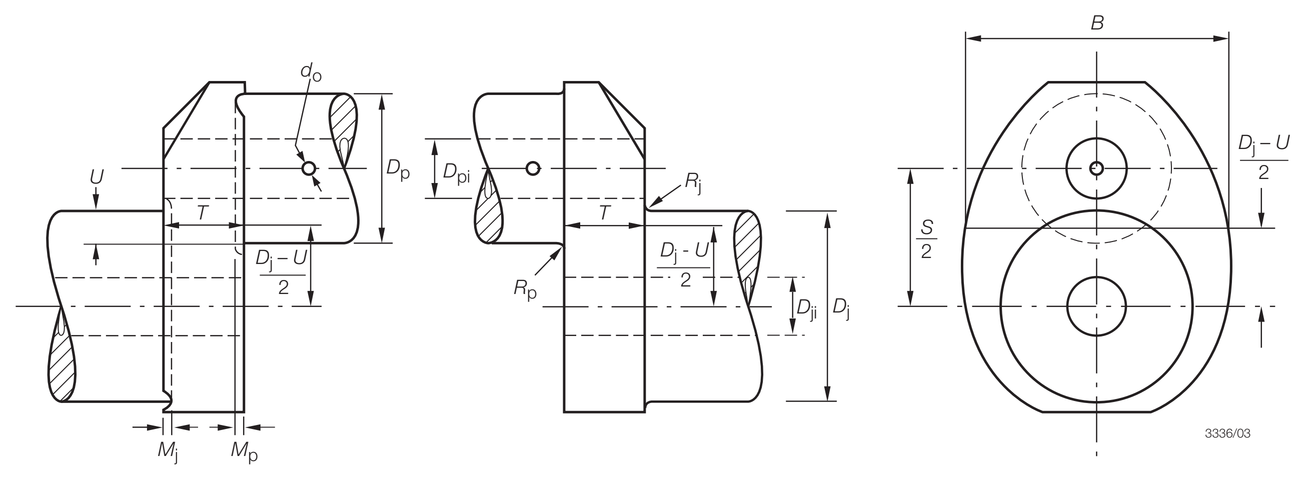
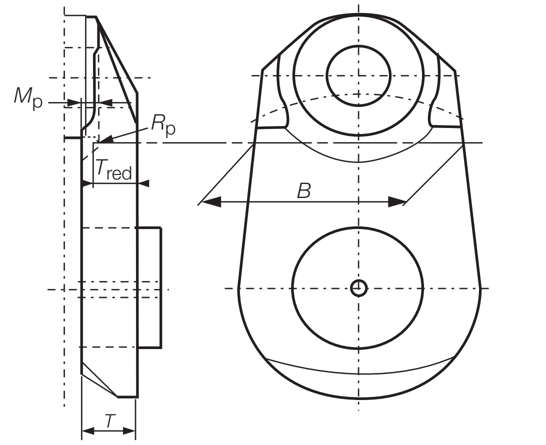


Fig. 2.3.2(a) Crank dimensions necessary for the calculation of stress concentration factors



Crankshaft without overlap

Fig. 2.3.2(b)
Crank dimensions for crankshaft without overlap

σ_Q = alternating direct stress, in N/mm^2
σ_U = specified minimum UTS of material, in N/mm^2
σ_y = specified minimum yield stress of material, in N/mm^2
τ_a = alternating torsional stress, in N/mm^2
τ_p, τ_j = maximum torsional stress in pin and main journals, taking into account stress raisers, in N/mm^2
τ_{tob} = maximum torsional stress in outlet of crankpin oil bore, taking into account stress raisers, in N/mm^2.

3.4 Stress concentration factors

3.4.1 **Geometric factors**. Crankshaft variables to be used in calculating the geometric stress concentrations together with their limits of applicability are shown in Table 2.3.1.

3.4.2 Crankpin stress concentration factors:

- Bending

α_B = 2,70 f(ut). f(t). f(b). f(r). f(dp). f(dj). f(rec)

where

f(ut) = $1{,}52 - 4{,}1t + 11{,}2t^2 - 13{,}6\,t^3 + 6{,}07t^4 - u\,(1{,}86 - 8{,}26t + 18{,}2t^2 - 18{,}5t^3 + 6{,}93t^4) - u^2\,(3{,}84 - 25{,}0t + 70{,}6t^2 - 87{,}0t^3 + 39{,}2t^4)$

f(t) = $2{,}18t^{0{,}717}$

f(b) = $0{,}684 - 0{,}0077b + 0{,}147b^2$

f(r) = $0{,}208r_p^{(-0{,}523)}$

f(dp) = $1 + 0{,}315(d_p) - 1{,}52(d_p)^2 + 2{,}41(d_p)^3$

f(dj) = $1 + 0{,}27d_j - 1{,}02(d_j)^2 + 0{,}531(d_j)^3$

f(rec) = $1 + (m_p + m_j)\,(1{,}8 + 3{,}2u)$
valid only between $u = -0{,}5$ and 0,5.

- Torsion

α_T = 0,8 f(ru). f(b). f(t)

where

f(ru) = $r_p^{-(0{,}22\,+\,0{,}1u)}$

f(b) = $7{,}9 - 10{,}65b + 5{,}35b^2 - 0{,}857b^3$

f(t) = $t^{\,(-0{,}145)}$.

Table 2.3.1 Crankshaft variables

Variable	Range Lower	Range Upper
$b = B/D_p$	1,10	2,20
$d_j = D_{ji}/D_p$	0,00	0,80
$d_p = D_{pi}/D_p$	0,00	0,80
$m_j = M_j/D_p$	0,00	r_{jB}
$m_p = M_p/D_p$	0,00	r_p
$r_{jB} = R_j/D_p$	0,03	0,13
$r_{jT} = R_j/D_j$	0,03	0,13
$r_p = R_p/D_p$	0,03	0,13
$t = T/D_p$	0,20	0,80
$t = T_{red}/D_p$ *see* Note 3	0,20	0,80
$d = d_o/D_p$	0,00	0,20
$u = U/D_p$ *see* Note 2		0,50

NOTES
1. Where variables fall outside the range, alternative methods are to be used and full details submitted for consideration.
2. A lower limit of *u* can be extended down to large negative values provided that:
   (i) If calculated *f*(rec) < 1 then the factor *f*(rec) is not to be considered (*f*(rec) = 1)
   (ii) If *u* < –0,5 then *f*(ut) and *f*(ru) are to be evaluated replacing actual value of *u* by –0,5.
3. For crankshafts without overlap *see also* 3.4.6.

3.4.3 Crank journal stress concentration factors (not applicable to semi-built crankshafts):

- Bending

β_B = 2,71f$_B$(ut). f$_B$(t). f$_B$(b). f$_B$(r). f$_B$(dj). f$_B$(dp). f(rec)

where

f$_B$(ut) = $1{,}2 - 0{,}5t + 0{,}32t^2 - u\,(0{,}80 - 1{,}15t + 0{,}55t^2) - u^2\,(2{,}16 - 2{,}33t + 1{,}26t^2)$

f$_B$(t) = $2{,}24t^{0{,}755}$

f$_B$(b) = $0{,}562 + 0{,}12b + 0{,}118b^2$

f$_B$(r) = $0{,}191r_{jB}^{(-0{,}557)}$

f$_B$(dj) = $1 - 0{,}644d_j + 1{,}23(d_j)^2$

f$_B$(dp) = $1 - 0{,}19d_p + 0{,}0073(d_p)^2$

f(rec) = $1 + (m_p + m_j)\,(1{,}8 + 3{,}2u)$
valid only between $u = -0{,}5$ and 0,5.

- Direct shear

β_Q = 3,01f$_Q$(u). f$_Q$(t). f$_Q$(b). f$_Q$(r). f$_Q$(dp). f(rec)

where

f$_Q$(u) = $1{,}08 + 0{,}88u - 1{,}52u^2$

f$_Q$(t) = $\dfrac{t}{0{,}0637 + 0{,}937t}$

f$_Q$(b) = $b - 0{,}5$

f$_Q$(r) = $0{,}533r_{JB}^{(-0{,}204)}$

f$_Q$(dp) = $1 - 1{,}19d_p + 1{,}74(d_p)^2$

f(rec) = $1 + (m_p + m_j)\,(1{,}8 + 3{,}2u)$
valid only between $u = -0{,}5$ and 0,5.

- Torsion

where

β_T = 0,8f(ru). f(b). f(t)

f(ru) = $r_{jT}^{-(0{,}22\,+\,0{,}1u)}$

f(b) = $7{,}9 - 10{,}65b + 5{,}35b^2 - 0{,}857b^3$

f(t) = $t^{\,(-0{,}145)}$.

3.4.4 Crankpin oil bore stress concentration factors for radially drilled oil holes:

- Bending

$$\gamma_B = 3 - 5{,}88 \bullet \frac{d_o}{D_p} + 34{,}6 \bullet \left(\frac{d_o}{D_p}\right)^2$$

- Torsion

$$\gamma_T = 4 - 6 \bullet \frac{d_o}{D_p} + 30 \bullet \left(\frac{d_o}{D_p}\right)^2$$

3.4.5 Where experimental measurements of the stress concentrations are available these may be used. The full documented analysis of the experimental measurements is to be submitted for consideration.

3.4.6 In the case of semi-built crankshafts when $M_p > R_p$ the web thickness is to be taken as:

T_{red} = $T - (M_p - R_p)$ and the web width B is to be taken in way of the crankpin fillet radius centre, *see* Fig. 2.3.2.

3.5 Nominal stresses

3.5.1 The nominal alternating bending stress, σ_b, is to be calculated from the maximum and minimum bending moment at the web centreline, taking into account all forces being applied to the crankthrow in one working cycle with the crankthrow simply supported at the mid length of the main journals.

3.5.2 Nominal bending stresses are referred to the web bending modulus.

3.5.3 Nominal alternating bending stress:

$$\sigma_b = \pm \frac{M_b}{Z_{web}} k_e \quad \text{N/mm}^2$$

$$Z_{web} = \frac{BT^2}{6} \quad \text{mm}^3$$

k_e = 0,8 for crosshead engines
= 1,0 for trunk piston engines.

3.5.4 Nominal alternating bending stress in the outlet of the crankpin oil bore:

$$\sigma_{BON} = \pm \frac{M_{BON}}{Z_{crankpin}}$$

where

M_{BON} is taken as the 1/2 range value $M_{BON} = \pm \frac{1}{2}(M_{BOmax} - M_{BOmin})$

and

M_{BO} = (M_{BTO} cosψ + M_{BRO} sinψ), *see* Fig. 2.3.3

The two relevant bending moments are taken in the crankpin cross-section through the oil bore.

M_{BRO} = bending moment of the radial component of the connecting-rod force

M_{BTO} = bending moment of the tangential component of the connecting-rod force

$$Z_{crankpin} = \frac{\pi}{32} \frac{D^4 - d^4}{D}$$ $Z_{crankpin}$ related to the cross-section of axially bored crankpin.

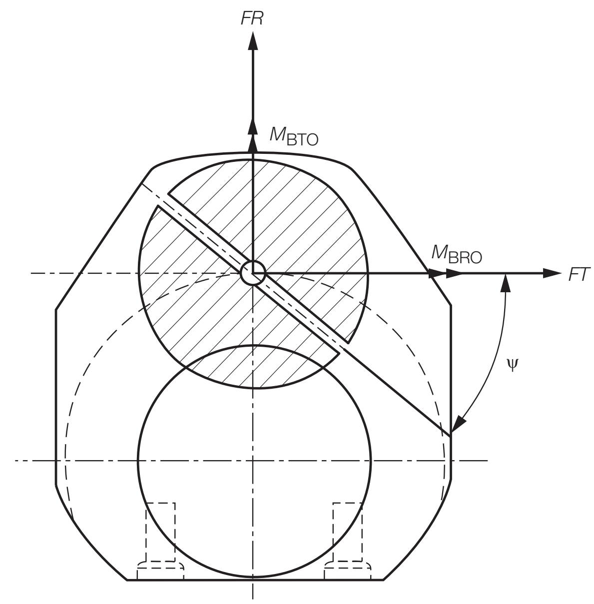


Fig. 2.3.3 Crankpin section through the oil bore

3.5.5 The nominal direct shear stress in the web for the purpose of assessing the main journal is to be added algebraically to the bending stress, using the alternating forces which have been used in deriving M_b in 3.5.3.

3.5.6 Nominal stress is referred to the web cross-section area or the pin cross-section area as applicable.

3.5.7 Nominal alternating direct shear stress:

$$\sigma_Q = \pm \frac{F}{A_{web}} k_e \quad \text{N/mm}^2$$

where

A_{web} = BT mm².

3.5.8 The nominal alternating torsional stress, τ_a, is to be taken into consideration. The value is to be derived from forced-damped vibration calculations of the complete dynamic system. Alternative methods will be given consideration. The engine designer is to advise the maximum level of alternating vibratory stress that is permitted.

3.5.9 The results of torsional vibration calculations for the full dynamic system, carried out in accordance with Ch 8,2.2, are to be submitted.

3.5.10 Nominal alternating torsional stress:

$$\tau_a = \pm \frac{T_a}{Z_T} \quad \text{N/mm}^2$$

where

S_T = torsional modulus of crankpin and main journal

$$= \frac{\pi}{16}\left[\frac{(D^4 - d^4)}{D}\right] \quad \text{mm}^3$$

D = outside diameter of crankpin or main journal, in mm

d = inside diameter of crankpin or main journal, in mm

τ_a is to be ascertained from assessment of the torsional vibration calculations where the maximum and minimum torques are determined for every mass point of the complete dynamic system and for the entire speed range by means of a harmonic synthesis of the forced vibrations from the 1st order up to and including the 15th order for 2-stroke cycle engines and from the 0,5th order up to and including the 12th order for 4-stroke cycle engines.
Whilst doing so, allowance must be made for the damping that exists in the system and for unfavourable conditions (misfiring in one of the cylinders when no combustion occurs but only compression cycle). The speed step calculation shall be selected in such a way that any resonance found in the operational speed range of the engine shall be detected.

3.5.11 For the purpose of the crankshaft assessment, the nominal alternating torsional stress considered in calculations is to be the highest calculated value, according to the method described in 3.5.9, occurring at the most torsionally loaded mass point of the crankshaft system.

3.5.12 The approval of the crankshaft will be based on the installation having the largest nominal alternating torsional stress (but not exceeding the maximum figure specified by the engine manufacturer). For each installation it is to be ensured by calculation that the maximum approved nominal alternating torsional stress is not exceeded.

3.5.13 In addition to the bending stress, σ_b, the axial vibratory stress, σ_{ax}, is to be taken into consideration, for crosshead type engines. For trunk type engines, $\sigma_{ax} = 0$. The value is to be derived from forced-damped vibration calculations of the complete dynamic system. Alternative methods will be given consideration. The engine designer is to advise the maximum level of alternating vibratory stress that is permitted. The corresponding crankshaft free-end deflection is also to be stated.

3.6 Maximum stress levels

3.6.1 Crankpin fillet.

- Maximum alternating bending stress:

$$\sigma_p = \alpha_B (\sigma_b + \sigma_{ax}) \text{ N/mm}^2$$

where
α_B = bending stress concentration, *see* 3.4.2

- Maximum alternating torsional stress:

$$\tau_p = \alpha_T \ \tau_a \text{ N/mm}^2$$

where
α_T = torsional stress concentration, *see* 3.4.2
τ_a = nominal alternating torsional stress in crankpin, N/mm^2.

3.6.2 Outlet of crankpin oil bore.

- Maximum alternating bending stress:

$$\sigma_{BO} = \gamma_B (\sigma_{BON} + \sigma_{ax}) \text{ N/mm}^2$$

where
γ_B = bending stress concentration factor, *see* 3.4.4

- Maximum alternating torsional stress:

$$T_{tob} = \gamma_T \ \tau_a \text{ N/mm}^2$$

where
γ_T = torsional stress concentration factor, *see* 3.4.4
τ_a = nominal alternating torsional stress in crankpin, N/mm^2.

3.6.3 Crank journal fillet (not applicable to semi-built crankshafts).

- Maximum alternating bending stress:

$$\sigma_j = \beta_B (\sigma_b + \sigma_{ax}) + \beta_Q \sigma_Q \text{ N/mm}^2$$

where
β_B = bending stress concentration, *see* 3.4.3
β_Q = direct stress concentration, *see* 3.4.3

- Maximum alternating torsional stress:

$$\tau_j = \beta_T \tau_a \text{ N/mm}^2$$

where
β_T = torsional stress concentration, *see* 3.4.3
τ_a = nominal alternating torsional stress in main journal, N/mm^2.

3.7 Equivalent alternating stress

3.7.1 Equivalent alternating stress of the crankpin, σ_{ep}, or crank journal σ_{ej}, is defined as:

$$\sigma_{ep}, \sigma_{ej} = \sqrt{(\sigma + 10)^2 + 3\tau^2} \quad \text{N/mm}^2$$

where
σ = σ_p or σ_j N/mm^2
τ = τ_p or τ_j N/mm^2.

3.7.2 Equivalent alternating stress for the outlet of the crankpin oil bore σ_{eob}, is defined as:

$$\sigma_{eob} = \pm \frac{1}{3} \sigma_{bo} \ 1 + 2\sqrt{1 + \frac{9}{4} \ \frac{\tau_{to}}{\sigma_{bo}}^{2}} \quad \text{N/mm}^2$$

3.8 Fatigue strength

3.8.1 The fatigue strength of a crankshaft is based upon the crankpin and crank journal as follows:

$$\sigma_{fp} = K_1 K_2 (0{,}42\sigma_u + 39{,}3) \left(0{,}264 + 1{,}073 D_p^{-0{,}2} + \frac{785 - \sigma_u}{4900} + \frac{196}{\sigma_u}\sqrt{\frac{1}{R_p}}\right)$$

To calculate the fatigue strength in the oil bore area, replace R_p with $^1/_2 d_o$ and σ_{fp} with σ_{fob}.

$$\sigma_{fj} = K_1 K_2 (0{,}42\sigma_u + 39{,}3) \left(0{,}264 + 1{,}073 D_j^{-0{,}2} + \frac{785 - \sigma_u}{4900} + \frac{196}{\sigma_u}\sqrt{\frac{1}{R_j}}\right)$$

where
σ_u = UTS of crankpin or crank journal as appropriate
K_1 = fatigue endurance factor appropriate to the manufacturing process
= 1,05 for continuous grain-flow (CGF) or die-forged
= 1,0 for freeform forged (without CGF)
= 0,93 for cast steel manufactured using a LR approved cold rolling process
K_2 = fatigue enhancement factor for surface treatment.

These treatments are to be applied to the fillet radii A value for K_2 will be assigned upon application by the engine designers. Full details of the process, together with the results of full scale fatigue tests, will be required to be submitted for consideration. Alternatively, the following values may be taken (surface-hardened zone to include fillet radii):

K_2 = 1,15 for induction-hardened
= 1,25 for nitrided

where a value of K_1 or K_2 greater than unity is to be applied then details of the manufacturing process are to be submitted.

3.9 Acceptability criteria

3.9.1 The acceptability factor, Q, is to be greater than 1,15:

$$Q = \frac{\sigma_f}{\sigma_e}$$ for crankpin, journal and the outlet of crankpin oil bore

where

$\sigma_f = \sigma_{fp}$ or σ_{fj} or σ_{fob}

$\sigma_e = \sigma_{ep}$ or σ_{ej} or σ_{eob}.

3.10 Oil hole

3.10.1 The junction of the oil hole with the crankpin or main journal surface is to be formed with an adequate radius and smooth surface finish down to a minimum depth equal to 1,5 times the oil bore diameter.

3.10.2 Fatigue strength calculations or, alternatively, fatigue test results may be required to demonstrate acceptability.

3.10.3 When journal diameter is equal to or larger than the crankpin diameter, the outlets of main journal oil bores are to be formed in a similar way to the crankpin oil bores, otherwise separate fatigue strength calculations or, alternatively, fatigue test results may be required.

3.11 Shrink fit of semi-built crankshafts

3.11.1 The maximum permissible internal diameter in the journal pin is to be calculated in accordance with the following formula:

$$D_{ji} = D_s \sqrt{1 - \frac{4000 \mathrm{FoS}\, M_{max}}{\mu \pi D_s^2 L_s \sigma_{yj}}}$$

where the symbols are as defined in 3.11.7.

3.11.2 When 3.11.1 cannot be complied with, then 3.11.7 is not applicable. In such cases, δ_{min} and δ_{max} are to be established from FEM calculations.

3.11.3 The following formulae are applicable to crankshafts assembled by shrinking main journals into the crankwebs.

3.11.4 In general, the radius of transition, R_j, between the main journal diameter, D_j, and the shrink diameter, D_s, is to be not less than $0{,}015D_j$ or $0{,}5\,(D_s - D_j)$.

3.11.5 The distance, y, between the underside of the pin and the shrink diameter should be greater than $0{,}05D_s$.

3.11.6 Deviations from these parameters will be specially considered.

3.11.7 The proposed diametral interference is to be within the following limits, *see also* Fig. 2.3.4. The minimum required diametral interference is to be taken as the greater of:

$$\delta_{min} = \frac{12{,}156 \times 10^6\,(\mathrm{FoS})}{T D_s \mu E} \frac{P}{R} (1 + C) \frac{k^2 - l^2}{(k^2 - 1)(1 - l^2)} \text{ mm}$$

or

$$\delta_{min} = \frac{\sigma_y D_s}{E} \text{ mm}$$

where

h = minimum radial thickness of the web around the diameter D_s, in mm

$k = \frac{D_o}{D_s}$

$l = \frac{D_{ji}}{D_s}$

C = ratio of torsional vibratory torque to the mean transmitted torque at the P/R rating being considered

$D_o = D_s + 2h$, in mm

D_s = shrink diameter, in mm

E = Young's modulus of elasticity of crankshaft material, in N/mm^2

FoS = Factor of Safety against rotational slippage to be taken as 2,0. A value less than 2,0 may be used where documented by experiments to demonstrate acceptability

P = output power, in kW

R = speed at associated power, in rpm

T = crankweb thickness, in mm

μ = coefficient of static friction to be taken as 0,2 for degreased surfaces. A value greater than 0,2 may be used where documented by experiments to demonstrate acceptability

σ_{yj} = minimum yield strength of material for journal pin

M_{max} = absolute maximum value of the torque taking Ch 8,2 into consideration

L_s = length of shrink fit, in mm.

Maximum diametral interference, δ_{max}, is not to be greater than:

$$\delta_{max} = \frac{\sigma_y D_s}{E} + \frac{0{,}8D_s}{1000} \text{ mm.}$$

3.11.8 Reference marks are to be provided on the outer junction of the crankwebs with the journals.

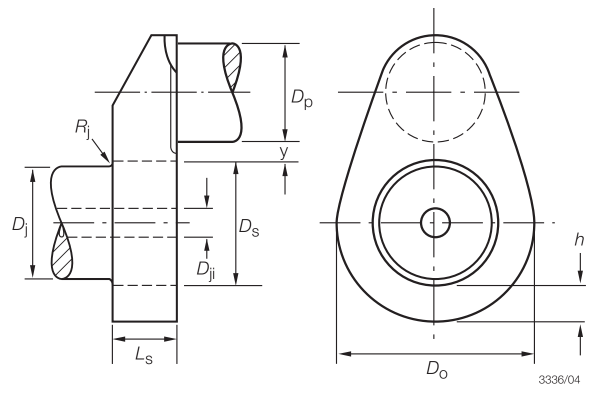


Fig. 2.3.4 Crank throw of semi-built crankshaft

■ *Section 4* Construction and welded structures

4.1 Crankcases

4.1.1 Crankcases and their doors are to be of robust construction to withstand anticipated crankcase pressures that may arise during a crankcase explosion, taking into account the installation of explosion relief valves required by Section 6, and the doors are to be securely fastened so that they will not be readily displaced by a crankcase explosion.

4.2 Welded joints

4.2.1 Bedplates and major components of engine structures are to be made with a minimum number of welded joints.

4.2.2 Double welded butt joints are to be adopted wherever possible in view of their superior fatigue strength.

4.2.3 Girder and frame assemblies should, so far as possible, be made from one plate or slab, shaped as necessary, rather than by welding together a number of small pieces.

4.2.4 Steel castings are to be used for parts which would otherwise require complicated weldments.

4.2.5 Care is to be taken to avoid stress concentrations such as sharp corners and abrupt changes in section.

4.2.6 Joints in parts of the engine structure which are stressed by the main gas or inertia loads are to be designed as continuous full strength welds and for complete fusion of the joint. They are to be so arranged that, in general, welds do not intersect, and that welding can be effected without difficulty and adequate inspection can be carried out. Abrupt changes in plate section are to be avoided and, where plates of substantially unequal thickness are to be butt welded, the thickness of the heavier plate is to be gradually tapered to that of the thinner plate. Tee joints are to be made with full bevel or equivalent weld preparation to ensure full penetration.

4.2.7 In single plate transverse girders the castings for main bearing housings are to be formed with web extensions which can be butt welded to the flange and vertical web plates of the girder. Stiffeners in the transverse girder are to be attached to the flanges by full penetration welds.

4.3 Materials and construction

4.3.1 Plates, sections, forgings and castings are to be of welding quality in accordance with the requirements of the Rules for Materials, and with a carbon content generally not exceeding 0,23 per cent. Steels with higher carbon contents may be approved subject to satisfactory results from welding procedure tests.

4.3.2 Welding is to be carried out in accordance with the requirements of Chapter 13 of the Rules for Materials, using welding procedures and welders that have been qualified in accordance with Chapter 12 of the Rules for Materials.

4.3.3 Before welding is commenced, the component parts of bedplates and framework are to be accurately fitted and aligned.

4.3.4 The welding is to be carried out in positions free from draughts and is to be downhand (flat) wherever practicable. Welding consumables are to be suitable for the materials being joined. Preheating is to be adopted when heavy plates or sections are welded. The finished welds are to have an even surface and are to be free from undercutting.

4.3.5 Welds attaching bearing housings to the transverse girders are to have a smooth contour and, if necessary, are to be made smooth by grinding.

4.4 Post-weld heat treatment

4.4.1 Bedplates are to be given a stress-relieving heat treatment except engine types where the bedplate as a whole is not subjected to direct loading from the cylinder pressure. For these types, only the transverse girder assemblies need be stress-relieved.

4.4.2 Stress-relieving is to be carried out by heating the welded structure uniformly and slowly to a temperature between 580°C and 620°C, holding that temperature for not less than one hour per 25 mm of maximum plate thickness and thereafter allowing the structure to cool slowly in the furnace.

4.4.3 Omission of post-weld heat treatment of bedplates and their sub-assemblies will be considered on application by the Enginebuilder with supporting evidence in accordance with Ch 13,2.10.4 of the Rules for Materials.

4.5 Inspection

4.5.1 Welded engine structures are to be examined during fabrication, special attention being given to the fit of component parts of major joints prior to welding.

4.5.2 Inspection of welds is to be in accordance with the requirements of Ch 13,1.11 of the Rules for Materials.

4.5.3 Welds in transverse girder assemblies are to be crack detected by an approved method to the satisfaction of the Surveyors. Other joints are to be similarly tested if required by the Surveyors.

■ *Section 5*
Safety arrangements on engines

5.1 Cylinder relief valves

5.1.1 Scavenge spaces in open connection with cylinders are to be provided with explosion relief valves.

5.2 Main engine governors

5.2.1 An efficient governor is to be fitted to each main engine so adjusted that the speed does not exceed that for which the engine is to be classed by more than 15 per cent.

5.2.2 Oil engines coupled to electrical generators which are the source of power for main electric propulsion motors are to comply with the requirements for auxiliary engines in respect of governors and overspeed protection devices.

5.3 Auxiliary engine governors

5.3.1 Auxiliary engines intended for driving electric generators are to be fitted with governors which, with fixed setting, are to control the speed within 10 per cent momentary variation and 5 per cent permanent variation when full load is suddenly taken off or, when after having run on no-load for at least 15 minutes, load is suddenly applied as follows:

(a) For engines with BMEP less than 8 bar, full load, or
(b) For engines with BMEP greater than 8 bar, $\frac{800}{\text{BMEP}}$ per cent, but not less than one third, of full load, the full load being attained in not more than two additional equal stages as rapidly as possible.

5.3.2 Emergency engines are to comply with 5.3.1, except that the initial load required by 5.3.1(b) is to be not less than the total connected emergency statutory load, or if their total consumer load is applied in steps, the following requirements are to be met:

(a) the total load is supplied within 45 seconds from power failure on the main switchboard;
(b) the maximum step load is declared and demonstrated; and
(c) the power distribution system is designed such that the declared maximum step loading is not exceeded.

5.3.3 Compliance of time delays and loading sequence with the requirements of 5.3.2 is to be demonstrated at trials.

5.3.4 For alternating current installations, the permanent speed variation of the machines intended for parallel operation are to be equal within a tolerance of ±0,5 per cent. Momentary speed variations with load changes in accordance with 5.3.1 are to return to and remain within one per cent of the final steady state speed. This should normally be accomplished within five but in no case more than eight seconds. For quality of power supplies, *see* Pt 6, Ch 2,1.8.

5.4 Overspeed protective devices

5.4.1 Each main engine developing 220kW (300 shp) or over which can be declutched or which drives a controllable (reversible) pitch propeller, also each auxiliary engine developing 220 kW (300 shp) and over for driving an electric generator, is to be fitted with an approved overspeed protective device.

5.4.2 The overspeed protective device, including its driving mechanism, is to be independent of the governor required by 5.2 or 5.3 and is to be so adjusted that the speed does not exceed that for which the engine and its driven machinery are to be classed by more than 20 per cent for main engines and 15 per cent for auxiliary engines.

■ *Section 6*
Crankcase safety fittings

6.1 Relief valves

6.1.1 Crankcases are to be provided with lightweight spring-loaded valves or other quick-acting and self-closing devices, to relieve the crankcases of pressure in the event of an internal explosion and to prevent any inrush of air thereafter. The valves are to be designed and constructed to open quickly and be fully open at a pressure not greater than 0,2 bar.

6.1.2 The valve lids are to be made of ductile material capable of withstanding the shock of contact with stoppers at the full open position.

6.1.3 Each valve is to be fitted with a flame arrester that permits flow for crankcase pressure relief and prevents the passage of flame following a crankcase explosion. The valves are to be type tested in a configuration that represent the installation arrangements that will be used on an engine and in accordance with Section 13. The valves are to be positioned on engines to minimise the possibility of danger and damage arising from emission of the crankcase atmosphere. Where shielding from the emissions is fitted to a valve, the valve is to be type tested to demonstrate that the shielding does not adversely affect the operational effectiveness of the valve.

6.1.4 The valves are to be provided with a copy of the manufacturer's installation and maintenance manual for the size and type of valve being supplied for installation on a particular engine. The manual is to contain the following information:

- Description of valve with details of function and design limits.
- Copy of type test certification.
- Installation instructions.
- Maintenance and in-service instructions to include testing and renewal of any sealing arrangements.
- Actions required after a crankcase explosion.

6.1.5 A copy of the installation and maintenance manual required by 6.1.4 is to be provided on board the unit.

6.1.6 Plans showing details and arrangements of the relief valves are to be submitted for approval, *see* 1.1.

6.1.7 The valves are to be provided with suitable markings that include the following information:

- Name and address of manufacturer.
- Designation and size.
- Month/Year of manufacture.
- Approved installation orientation.

6.2 Number of relief valves

6.2.1 In engines having cylinders not exceeding 200 mm bore or having a crankcase gross volume not exceeding 0,6 m^3, relief valves may be omitted.

6.2.2 In engines having cylinders exceeding 200 mm but not exceeding 250 mm bore, at least two relief valves are to be fitted; each valve is to be located at or near the ends of the crankcase. Where the engine has more than eight crank throws, an additional valve is to be fitted near the centre of the engine.

6.2.3 In engines having cylinders exceeding 250 mm but not exceeding 300 mm bore, at least one relief valve is to be fitted in way of each alternate crank throw with a minimum of two valves. For engines having 3, 5, 7, 9, etc., crank throws, the number of relief valves is not to be less than 2, 3, 4, 5, etc., respectively.

6.2.4 In engines having cylinders exceeding 300 mm bore, at least one valve is to be fitted in way of each main crank throw.

6.2.5 Additional relief valves are to be fitted for separate spaces on the crankcase, such as gear or chaincases for camshaft or similar drives, when the gross volume of such spaces exceeds 0,6 m^3.

6.3 Size of relief valves

6.3.1 The combined free area of the crankcase relief valves fitted on an engine is to be not less than 115 cm^2/m^3, based on the volume of the crankcase.

6.3.2 The free area of each relief valve is to be not less than 45 cm^2.

6.3.3 The free area of the relief valve is the minimum flow area at any section through the valve when the valve is fully open.

6.3.4 In determining the volume of the crankcase for the purpose of calculating the combined free area of the crankcase relief valves, the volume of the stationary parts within the crankcase may be deducted from the total internal volume of the crankcase.

6.4 Vent pipes

6.4.1 Through ventilation, and any arrangement which could produce a flow of external air within the crankcase, is in principle not permitted, except for trunk piston type dual fuel engines where crankcase ventilation is to be provided. Where crankcase vent or breather pipes are fitted, they are to be made as small as practicable and/or as long as possible to minimise the inrush of air after an explosion. Vents or breather pipes from crankcases of main engines are to be led to a safe position on deck or other approved position.

6.4.2 If provision is made for the extraction of gases from within the crankcase, e.g., for oil mist detection purposes, the vacuum within the crankcase is not to exceed 25 mm of water.

6.4.3 Lubricating oil drain pipes from engine sump to drain tank are to be submerged at their outlet ends. Where two or more engines are installed, vent pipes, if fitted, and lubrication oil drain pipes are to be independent to avoid intercommunication between crankcases.

6.5 Warning notice

6.5.1 A warning notice is to be fitted in a prominent position, preferably on a crankcase door on each side of the engine, or alternatively at the engine room control station. This warning notice is to specify that whenever overheating is suspected in the crankcase, the crankcase doors or sight holes are not to be opened until a reasonable time has elapsed after stopping the engine, sufficient to permit adequate cooling within the crankcase.

6.6 Crankcase access and lighting

6.6.1 Where access to crankcase spaces is necessary for inspection purposes, suitably positioned rungs or equivalent arrangements are to be provided, as considered appropriate.

6.6.2 When interior lighting is provided, it is to be flameproof in relation to the interior and details are to be submitted for approval. No wiring is to be fitted inside the crankcase.

6.7 Fire-extinguishing system for scavenge manifolds

6.7.1 Crosshead type engine scavenge spaces in open connection with cylinders are to be provided with approved fixed or portable fire-extinguishing arrangements, which are to be independent of the fire-extinguishing system of the engine room.

6.8 Oil mist detection

6.8.1 Where crankcase oil mist detection arrangements are fitted, they are to be of a type approved by LR, tested in accordance with Section 14 and are to comply with 6.8.2 to 6.8.15.

6.8.2 The oil mist detection system and arrangements are to be installed in accordance with the engine designer's and oil mist detection equipment manufacturer's instructions/ recommendations. The following particulars are to be included in the instructions:

(a) A schematic layout of the engine oil mist detection and alarm system, showing locations of engine crankcase sample points and cabling/piping arrangements together with pipe dimensions to the detector.

(b) Evidence of study to justify the selected locations of sample points and sample extraction rate (if applicable) in consideration of the crankcase arrangements and geometry and the predicted crankcase atmosphere where oil mist can accumulate.

(c) The manufacturer's maintenance and test manual.

(d) Information relating to type or in-service testing of the engine with engine protection system test arrangements having approved types of oil mist detection equipment.

6.8.3 A copy of the oil mist detection equipment maintenance and test manual required by 6.8.2 is to be provided on board.

6.8.4 Oil mist detection and alarm information is to be capable of being read from a safe location away from the engine.

6.8.5 In the case of multi engine installations, each engine is to be provided with individual dedicated oil mist detection arrangements and alarm(s).

6.8.6 Oil mist detection and alarm systems are to be capable of being tested on the test bed and on board when the engine is at a standstill and when the engine is running at normal operating conditions in accordance with test procedures that are acceptable to LR.

6.8.7 Alarms and safeguards for the oil mist detection system are to be in accordance with Pt 6, Ch 1, as applicable.

6.8.8 The oil mist detection arrangements are to provide an alarm indication in the event of a foreseeable functional failure in the equipment and installation arrangements. *See* Pt 6, Ch 1,2.4.6 of the *Rules and Regulations for the Classification of Ships (*hereinafter referred to as the Rules for Ships*)*.

6.8.9 The oil mist detection system is to provide an indication that any lenses fitted in the equipment and used in determination of the oil mist level have been partially obscured to a degree that will affect the reliability of the information and alarm indication.

6.8.10 Where oil mist detection equipment includes the use of programmable electronic systems, the arrangements are to be in accordance with Pt 6, Ch 1, as applicable.

6.8.11 Schematic layouts showing details and arrangements of oil mist detection and alarm systems are to be submitted. *See* Pt 5, Ch 1,1.

6.8.12 The equipment together with detectors is to be tested when installed on the test bed and on board to demonstrate that the detection and alarm system functions correctly. The testing arrangements are to be to the satisfaction of the Surveyor.

6.8.13 Where sequential oil mist detection arrangements are provided, the sampling frequency and time is to be as short as reasonably practicable.

6.8.14 Where alternative methods are provided for the prevention of the build-up of oil mist that may lead to a potentially explosive condition within the crankcase, detailed information is to be submitted for consideration. The information is to include:

(a) Engine particulars – type, power, speed, stroke, bore and crankcase volume.

(b) Details of arrangements designed to prevent the build-up of potentially explosive conditions within the crankcase, e.g., bearing temperature monitoring, oil splash temperature monitoring, crankcase pressure monitoring, and recirculation arrangements.

(c) Evidence to demonstrate that the arrangements are effective in preventing the build-up of potentially explosive conditions, together with details of in-service experience.

(d) Operating instructions and the maintenance and test instructions.

6.8.15 Where it is proposed to use the introduction of inert gas into the crankcase to minimise a potential crankcase explosion, details of the arrangements are to be submitted for consideration.

Section 7
Piping

7.1 Oil fuel systems

7.1.1 All external high pressure fuel delivery lines between the high pressure fuel pumps and fuel injectors are to be protected with a jacketed piping system capable of containing fuel from a high pressure line failure. If flexible hoses are used for shielding purposes, these arrangements are to be approved.

7.1.2 The protection is to prevent oil fuel or oil fuel mist from reaching a source of ignition on the engine or its surroundings. Suitable drainage arrangements are to be made for draining any oil fuel leakage to collector tank(s) fitted in a safe position. An alarm is to be provided to indicate that leakage is taking place.

7.1.3 Oil fuel pipe systems in general, tanks and their fittings are to comply with the requirements of Chapter 14 and Part 3.

7.1.4 Diesel engine fuel system components are to be designed to accommodate the maximum peak pressures experienced in service. In particular this applies to the fuel injection pump supply and spill line piping which may be subject to high-pressure pulses from the pump. Connections on such piping systems should be chosen to minimise the risk of pressurised oil fuel leaks.

7.1.5 Where multi-engined installations are supplied from the same fuel source, means of isolating the fuel supply and spill piping to individual engines are to be provided. These means of isolation are not to affect the operation of the other engines and are to be operable from a position not rendered inaccessible by a fire on any of the engines.

7.2 High pressure oil systems

7.2.1 Where flammable oils are used in high pressure systems, the oil pipe lines between the high pressure oil pump and actuating oil pistons are to be protected with a jacketed piping system capable of preventing oil spray from a high pressure line failure.

7.3 Exhaust systems

7.3.1 Where the surface temperature of the exhaust pipes and silencer may exceed 220ºC, they are to be water cooled or efficiently lagged to minimise the risk of fire and to prevent damage by heat. Where lagging covering the exhaust piping system including flanges is oil-absorbing or may permit penetration of oil, the lagging is to be encased in sheet metal or equivalent. In locations where the Surveyor is satisfied that oil impingement could not occur, the lagging need not be encased.

7.3.2 Where the exhaust is led overboard near the waterline, means are to be provided to prevent water from being siphoned back to the engine. Where the exhaust is cooled by water spray, the exhaust pipes are to be self-draining overboard.

7.3.3 Where the exhausts of two or more engines are led to a common silencer or exhaust gas-heated boiler or economiser, an isolating device is to be provided in each exhaust pipe.

7.3.4 For alternatively fired furnaces of boilers using exhaust gases and oil fuel, the exhaust gas inlet pipe is to be provided with an isolating device and interlocking arrangements whereby oil fuel can only be supplied to the burners when the isolating device is closed to the boiler.

7.3.5 In two-stroke main engines fitted with exhaust gas turbo-blowers which operate on the impulse system, provision is to be made to prevent broken piston rings entering the turbine casing and causing damage to blades and nozzle rings.

7.4 Starting air pipe systems and safety fittings

7.4.1 In designing the compressed air installation, care is to be taken that the compressor air inlets will be located in an atmosphere reasonably free from oil vapour or, alternatively, an air duct from outside the machinery space is to be led to the compressors.

7.4.2 The air discharge pipe from the compressors is to be led directly to the starting air receivers. Provision is to be made for intercepting and draining oil and water in the air discharge, for which purpose a separator or filter is to be fitted in the discharge pipe between compressors and receivers.

7.4.3 The starting air pipe system from receivers to main and auxiliary engines is to be entirely separate from the compressor discharge pipe system. Stop valves on the receivers are to permit slow opening to avoid sudden pressure rises in the piping system. Valve chests and fittings in the piping system are to be of ductile material.

7.4.4 Drain valves for removing accumulations of oil and water are to be fitted on compressors, separators, filters and receivers. In the case of any low-level pipelines, drain valves are to be fitted to suitably located drain pots or separators.

7.4.5 The starting air piping system is to be protected against the effects of explosions by providing an isolating non-return valve or equivalent at the starting air supply to each engine.

7.4.6 In direct reversing engines, bursting discs or flame arresters are to be fitted at the starting valves on each cylinder; in non-reversing and auxiliary engines, at least one such device is to be fitted at the supply inlet to the starting air manifold on each engine. The fitting of bursting discs or flame arresters may be waived in engines where the cylinder bore does not exceed 230 mm.

7.4.7 Alternative safety arrangements may be submitted for consideration.

Section 8
Air compressors and starting arrangements

8.1 General requirements

8.1.1 The requirements of this Section are applicable to reciprocating air compressors intended for starting main engines and auxiliary engines providing essential services.

8.1.2 Two or more air compressors are to be fitted having a total capacity, together with a topping-up compressor where fitted, capable of charging the air receivers within 1 hour from atmospheric pressure to the pressure sufficient for the number of starts required by 8.12. At least one of the air compressors is to be independent of the main propulsion unit and the capacity of the main air compressors is to be approximately equally divided between them. The capacity of an emergency compressor which may be installed to satisfy the requirements of 8.11 is to be ignored.

8.1.3 The compressors are to be so designed that the temperature of the air discharged to the starting air receivers will not substantially exceed 93°C in service. A small fusible plug or an alarm device operating at 121°C is to be provided on each compressor to give warning of excessive air temperature. The emergency air compressor is excepted from these requirements.

8.1.4 Each compressor is to be fitted with a safety valve so proportioned and adjusted that the accumulation with the outlet valve closed will not exceed 10 per cent of the maximum working pressure. The casings of the cooling water spaces are to be fitted with a safety valve or bursting disc so that ample relief will be provided in the event of the bursting of an air cooler tube. It is recommended that compressors be cooled by fresh water.

8.2 Plans and particulars

8.2.1 Detailed plans, particulars, dimensional drawings and material specifications for compressor crankshafts are to be submitted in triplicate. Plans and particulars for other parts and calculations where applicable are to be submitted to LR upon request.

8.2.2 Where compressors of a special type or design are proposed, the requirements of Pt 7, Ch 16 of the Rules for Ships are to be applied.

8.3 Materials

8.3.1 The specified minimum tensile strength of castings and forgings for compressor crankshafts is to be within the limits given in 2.1.1 and for grey cast iron is to be not less than 300 N/mm^2.

8.3.2 Where it is proposed to use materials outside the ranges specified in 8.3.1, details of the chemical composition, heat treatment and mechanical properties are to be submitted for approval.

8.3.3 Materials for components are to be tested as indicated in 2.2.

8.3.4 For crankshafts with a calculated crank pin diameter equal to or greater than 50 mm, they are to be manufactured and tested in accordance with the requirements of LR's Rules for Materials. For calculated crank pin diameters less than 50 mm, a manufacturers' certificate may be accepted, *see* Ch 1,3.1.3(c) of the Rules for Materials.

8.4 Design and construction

8.4.1 A fully documented fatigue strength analysis is to be submitted indicating a factor of safety of 1,5 at the design loads based on a suitable fatigue strength criterion. Alternatively, the requirements of 8.4.2 to 8.4.6 may be used.

8.4.2 The diameter, d_p, of a compressor crankshaft is to be not less than d, determined by the following formula, when all cranks on the shaft are located between two main bearings only:

$$d = v_c \left(\frac{D^2\, p\, Z}{78{,}5} \left(\frac{S}{16} + \frac{a\, b}{a + b} \right) \right)^{1/3} \text{ mm}$$

where

a = distance between inner edge of one main bearing and the centreline of the crankpin nearest the centre of the span, in mm

b = distance from the centreline of the same crankpin to the inner edge of the adjacent main bearing, in mm

$a + b$ = span between inner edges of main bearings, in mm

d_p = proposed minimum diameter of crankshaft, in mm

p = design pressure, in bar g, as defined in Ch 12,1.3.1

D = diameter of cylinder, in mm

S = length of stroke, in mm

V_c = 1,0 for shafts having one cylinder per crank, or
= 1,05 for 90°
= 1,18 for 60°
= 1,25 for 45°
} between adjacent cylinders on the same crankpin
for the shaft and cylinder arrangements as detailed in Table 2.8.1

$$Z = \frac{560}{\sigma_u + 160} \text{ for steel}$$

$$Z = \frac{700}{\sigma_u + 260 - 0{,}059 d_p} \text{ for spheroidal or nodular graphite cast iron}$$

$$Z = \frac{700}{\sigma_u + 260 - 0{,}069 d_p} \text{ for grey cast iron}$$

σ_u = specified minimum tensile strength of crankshaft material, in N/mm^2.

Table 2.8.1 Angle between cylinders

Number of crankpins	Number of cylinders per crank	Angle between cylinders, in degrees		
1 or 2 3 4	2 2 2	45 45 45	60 60 60	90 — —
1 2 3	3 3 3	45 45 45	60 60 —	90 — —
1 2	4 4	45 45	60 —	— —

8.4.3 Where the shaft is supported additionally by a centre bearing, the diameter is to be evaluated from the half shaft between the inner edges of the centre and outer main bearings. The diameter so found for the half shaft is to be increased by six per cent for the full length shaft diameter.

8.4.4 The dimensions of crankwebs are to be such that Bt^2 is to be not less than given by the following formulae:

$0{,}4d^3$ for the web adjacent to the bearing

$0{,}75d^3$ for intermediate webs

where

B = breadth of web, in mm

d = minimum diameter of crankshaft as required by 8.4.2, in mm

t = axial thickness of web which is to be not less than $0{,}45d$ for the web adjacent to the bearing, or $0{,}60d$ for intermediate webs, in mm.

8.4.5 Fillets at the junction of crankwebs with crankpins or journals are to be machined to a radius not less than $0{,}05d$. Smaller fillets, but of a radius not less than $0{,}025d$, may be used provided the diameter of the crankpin or journal is not less than cd,

where

$c = 1{,}1 - 2\dfrac{r}{d}$ but to be taken as not less than 1,0

d = minimum diameter of crankshaft as required by 8.4.2, in mm

r = fillet radius, in mm.

8.4.6 Fillets and oil holes are to be rounded to an even contour and smooth finish.

8.4.7 An oil level sight glass or oil level indicator is to be fitted to the crankcase.

8.4.8 The crankcases of compressors are to be designed to withstand a pressure equal to the maximum working pressure of the system.

8.4.9 Compressors with shaft power exceeding 500 kW are to have torsional vibration analysis determined in accordance with Ch 8,2 as applicable.

8.4.10 The cooler dimensions for sea-water cooled stage air coolers are to be based on an inlet temperature of not less than 32°C. Where fresh water cooling is used, the cooling water inlet temperature is not to be greater than 40°C.

8.4.11 The cooler dimensions for air cooled stage air coolers are to be based on an air temperature of not less than 45°C.

8.4.12 The piping to and from the air compressor is to be arranged to prevent condensation from entering the cylinders.

8.5 Testing

8.5.1 Cylinders and liners of air compressors are to be subjected to hydraulic pressure tests at 1,5 times the final pressure of the stage concerned.

8.5.2 The compressed air chambers of the intercoolers and after coolers of air compressors are to be subjected to hydraulic pressure tests at 1,5 times the final pressure of the stage concerned.

8.6 Safety arrangements and monitoring

8.6.1 Air compressors are to be arranged and located so as to minimise the intake of air contaminated by oil or water.

8.6.2 Where one compressor stage comprises several cylinders which can be shut off individually, each cylinder shall be equipped with a safety valve and a pressure gauge.

8.6.3 After the final stage, all air compressors are to be equipped with a water trap and after cooler. The water traps, after coolers and the compressed air spaces between the stages are to be provided with discharge devices at their lowest points.

8.6.4 Each compressor stage shall be fitted with a suitable pressure gauge, the scale of which must indicate the relevant maximum permissible working pressure.

8.7 Crankcase relief valves

8.7.1 In compressors having cylinders not exceeding 200 mm bore or having a crankcase gross volume not exceeding 0,6 m^3, crankcase relief valves may be omitted.

8.7.2 Crankcases are to be provided with lightweight spring-loaded valves or other quick-acting and self-closing devices to relieve the crankcases of pressure in the event of an internal explosion and to prevent any inrush of air thereafter. The valves are to be designed and constructed to open quickly and be fully open at a pressure not greater than 0,2 bar.

8.7.3 The valve lids are to be made of ductile material capable of withstanding the shock of contact with stoppers at the full open position.

8.7.4 Each valve is to be fitted with a flame arrester that permits flow for crankcase pressure relief and prevents the passage of flame following a crankcase explosion.

8.7.5 The valves are to be provided with a copy of the manufacturer's installation and maintenance manual for the size and type of valve being supplied. The manual is to contain the following information:

(a) Description of valve with details of function and design limits.
(b) Copy of type test certification.
(c) nstallation instructions.
(d) Maintenance and in-service instructions to include testing and renewal of any sealing arrangements.
(e) Actions required after a crankcase explosion.

8.7.6 A copy of the installation and maintenance manual required by 8.7.3 is to be provided on board the unit.

8.7.7 Plans showing details and arrangements of the crankcase relief valves are to be submitted for approval, *see* 1.1.

8.7.8 The valves are to be provided with suitable markings that include the following information:

(a) Name and address of manufacturer.
(b) Designation and size.
(c) Month/year of manufacture.
(d) Approved installation orientation.

8.8 Number of crankcase relief valves

8.8.1 In compressors having cylinders exceeding 200 mm but not exceeding 250 mm bore, at least two relief valves are to be fitted; where more than one relief valve is required, the valves are to be located at or near the ends of the crankcase.

8.8.2 In compressors having cylinders exceeding 250 mm but not exceeding 300 mm bore, at least one relief valve is to be fitted in way of each alternate crank throw with a minimum of two valves. For compressors having 3, 5, 7, 9, etc., crank throws, the number of relief valves is not to be less than 2, 3, 4, 5, etc., respectively.

8.8.3 In compressors having cylinders exceeding 300 mm bore, at least one valve is to be fitted in way of each main crank throw.

8.8.4 Additional relief valves are to be fitted for separate spaces on the crankcase, such as gear or chain cases, when the gross volume of such spaces exceeds 0,6 m^3.

8.9 Size of crankcase relief valves

8.9.1 The combined free area of the crankcase relief valves fitted on a compressor is to be not less than 115 cm^2/m^3 based on the volume of the crankcase.

8.9.2 The free area of each relief valve is to be not less than 45 cm^2.

8.9.3 The free area of the relief valve is the minimum flow area at any section through the valve when the valve is fully open.

8.9.4 In determining the volume of the crankcase for the purpose of calculating the combined free area of the crankcase relief valves, the volume of the stationary parts within the crankcase may be deducted from the total internal volume of the crankcase.

8.10 Vent pipes

8.10.1 Where crankcase vent or breather pipes are fitted, they are to be made as small as practicable and/or as long as possible to minimise the inrush of air after an explosion.

8.11 Dead ship condition starting arrangements

8.11.1 Means are to be provided to ensure that machinery can be brought into operation from the dead ship condition without external aid.

8.11.2 Dead ship condition for the purpose of 8.1.1 is to be understood to mean a condition under which the main propulsion plant, boilers and auxiliaries are not in operation. In restoring propulsion, no stored energy for starting and operating the propulsion plant is assumed to be available. Additionally, neither the main source of electrical power nor other essential auxiliaries are assumed to be available for starting and operating the propulsion plant.

8.11.3 Where the emergency source of power is an emergency generator which fully complies with the requirements of Pt 6, Ch 2, this generator may be used for restoring operation of the main propulsion plant, boilers and auxiliaries where any power supplies necessary for engine operation are also protected to a similar level as the starting arrangements.

8.11.4 Where there is no emergency generator installed or an emergency generator does not comply with Pt 6, Ch 2, the arrangements for bringing main and auxiliary machinery into operation are to be such that the initial charge of starting air or initial electrical power and any power supplies for engine operation can be developed on board without external aid. If for this purpose an emergency air compressor or an electric generator is required, these units are to be powered by a hand-starting oil engine or a hand-operated compressor. The arrangements for bringing main and auxiliary machinery into operation are to have capacity such that the starting energy and any power supplies for engine operation are available within 30 minutes of a dead ship condition.

8.12 Air receiver capacity

8.12.1 Where the main engine is arranged for air starting, the total air receiver capacity is to be sufficient to provide, without replenishment, no fewer than 12 consecutive starts of the main engine, alternating between ahead and astern if of the reversible type and no fewer than 6 consecutive starts if of the non-reversible type. At least two air receivers of approximately equal capacity are to be provided. For scantlings and fittings of air receivers, *see* Chapter 11.

8.12.2 For multi-engine installations, the number of starts required for each engine is to be as follows:

(a) Two engines through common reduction gearing:
6 starts per engine for fixed pitch propeller/propellers;
3 starts per engine for controllable pitch propeller/propellers.

(b) Three engines or more through common reduction gearing:
3 starts per engine.

8.12.3 No engine is to have fewer than 3 starts for any arrangement. For electric propulsion arrangements, a minimum of 3 starts per engine with a minimum capacity of 12 starts of the largest start air consumption engine in total is required.

8.13 Electric starting

8.13.1 Where main engines are fitted with electric starters, two batteries are to be fitted. Each battery is to be capable of starting the engines when cold and the combined capacity is to be sufficient without recharging to provide the number of starts of the main engines as required by 8.12. In other respects, batteries are to comply with the requirements of Pt 6, Ch 2,12.

8.13.2 Electric starting arrangements for auxiliary engines are to have two separate batteries or be supplied by separate circuits from the main engine batteries when such are provided. Where one of the auxiliary engines only is fitted with an electric starter, one battery will be acceptable.

8.13.3 The combined capacity of the batteries for starting the auxiliary engines is to be sufficient for at least three starts for each engine.

8.13.4 Engine starting batteries are to be used only for the purposes of starting the engines and for the engines' own control, alarm, monitoring and safety arrangements. Means are to be provided to ensure that the stored energy in the batteries is maintained at a level required to start the engines, as defined in 8.13.1 and 8.13.3.

8.13.5 Where engines are fitted with electric starting batteries, an alarm is to be provided for low battery charge level.

8.14 Starting of the emergency source of power

8.14.1 Emergency generators are to be capable of being readily started in their cold conditions down to a temperature of 0°C. If this is impracticable, or if lower temperatures are likely to be encountered, consideration is to be given to the provision and maintenance of heating arrangements, so that ready starting will be assured.

8.14.2 Each emergency generator that is arranged to be automatically started is to be equipped with an approved starting system having two independent sources of stored energy, each of which is sufficient for at least three consecutive starts. When hand (manual) starting is demonstrated to be effective, only one source of stored energy need be provided. However, this source of stored energy is to be protected against depletion below the level required for starting.

8.14.3 Provision is to be made to maintain continuously the stored energy at all times, and for this purpose:

(a) Electrical and hydraulic starting systems are to be maintained from the emergency switchboard.

(b) Compressed air starting systems may be maintained by the main or auxiliary compressed air receivers, through a suitable non-return valve, or by an emergency air compressor energised by the emergency switchboard.

(c) All these starting, charging and energy storing devices are to be located in the emergency generator room. These devices are not to be used for any purpose other than the operation of the emergency generator.

8.14.4 When automatic starting is not required by the Rules and where it can be demonstrated as being effective, hand (manual) starting is permissible, such as manual cranking, inertial starters, manual hydraulic accumulators, powder charge cartridges.

8.14.5 When hand (manual) starting is not practicable, the provisions under 8.14.2 and 8.14.3 are to be complied with, except that starting may be manually initiated.

8.14.6 Electric starting arrangements are also to satisfy 8.13.2 to 8.13.5.

8.15 Engine control, alarm monitoring and safety system power supplies

8.15.1 Power supplies are to be arranged so that power for electrically powered control, alarm, monitoring and safety systems required for engine starting and operation will remain available in the event of a failure. Power is to remain available to permit starting attempts for the number of starts specified by this Section for each individual source of stored energy.

8.15.2 Where adequate battery and charging capacity exists, an engine starting battery may be used as one source of electrical power required by 8.15.1.

8.15.3 An alarm is to be activated in the event of failure of a power supply and, where applicable, low battery charge level. Manual power supply changeover facilities are permitted.

Section 9 Component tests and engine type testing

9.1 Hydraulic tests

9.1.1 In general, items are to be tested by hydraulic pressure as indicated in Table 2.9.1. Where design features are such that modifications to the test requirements shown in Table 2.9.1 are necessary, alternative proposals for hydraulic tests are to be submitted for special consideration.

9.1.2 Where a manufacturer has demonstrated to LR that they have an acceptable quality management system, a manufacturer's hydraulic test certificate may be accepted for engine driven pumps as detailed in Table 2.9.1. Recognition and acceptance of the works, quality control processes can be by one of the following routes:

(a) Approval under the LR Quality Scheme for Machinery.
(b) Approval of an alternative quality scheme recognised by LR.
(c) Approval by LR through auditing of the manufacturer's quality system.

9.2 Alignment gauges

9.2.1 All main and auxiliary oil engines exceeding 220 kW (300 shp) are to be provided with an alignment gauge which may be either a bridge weardown gauge, or a micrometer clock gauge for use between the crankwebs. Only one micrometer clock gauge need be supplied for each unit provided the gauge is suitable for use on all engines.

9.3 Engine type testing

9.3.1 New engine types or developments of existing types are to be subjected to an agreed programme of type testing to complement the design appraisal and review of documentation.

9.3.2 Guidelines for type testing of engines will be supplied on application.

9.3.3 Wherever practical, type tests are to be conducted with the engine control systems operational in the approved configuration, *see* 1.1.4 and 1.1.5. Configuration management documents are to be reviewed at testing for validity and referenced in the type test report.

9.3.4 An engine type is defined in terms of:

- basic engine data: e.g. bore, stroke
- working cycle: 2 stroke, 4 stroke
- cylinder arrangement: in-line, vee
- cylinder rating
- fuel supply: e.g. direct, or indirect injection, dual fuel
- gas exchange: natural aspiration, pressure charging arrangement.

9.3.5 Where an engine type has subsequently proved satisfactory in service with a number of applications, a maximum uprating of 10 per cent may be considered without a further complete type test.

9.3.6 A type test will be considered to cover engines of a given design for a range of cylinder numbers in a given cylinder arrangement.

Table 2.9.1 Test pressures for oil engine components

Item	Test pressure
Fuel injection system: Pump body, pressure side; Valve; Pipe	The lesser of 1,5*p* or *p* + 300 bar
Cylinder cover, cooling space Cylinder liner, over the whole length of cooling space Piston crown, cooling space (where piston rod seals cooling space, test after assembly)	7,0 bar
Cylinder jacket, cooling space Exhaust valve, cooling space Turbo-charger, cooling space Exhaust pipe, cooling space Coolers, each side Engine driven pumps (oil, water, fuel, bilge)	The greater of 4,0 bar or 1,5*p*
Air compressor, including cylinders, covers, intercoolers and aftercoolers	Air side: 1,5*p* Water side: The greater of 4,0 bar or 1,5*p*
Scavenge pump cylinder	4,0 bar
Hydraulic systems (piping, pumps, actuators)	1,5*p*

NOTES
1. *p* is the maximum working pressure in the item concerned.
2. Pumps used in jerk or timed pump systems need only have the assembled high pressure-containing components hydraulically tested.
3. Turbo-charger air coolers need only be tested on the water side.
4. For forged steel cylinder covers and piston crowns, alternative testing methods may be specially considered.
5. For hydraulic systems where design features are such that modifications to the test requirements are necessary, alternative proposals for hydraulic tests are to be submitted for special consideration.

Section 10
Turbo-chargers

10.1 Plans and particulars

10.1.1 The following plans and particulars are to be submitted for information:

- Cross-sectional plans of the assembled turbocharger with main dimensions.
- Fully dimensioned plans of the rotor.
- Material particulars with details of welding and surface treatments.
- Turbo-charger operating and test data.
- A selected turbocharger is to be type tested.
- Manufacturer's burst test assessment.

10.2 Type test

10.2.1 A type test is to consist of a hot gas running test of at least one hour's duration at the maximum permissible speed and maximum permissible temperature. Following the test, the turbo-charger is to be completely dismantled for examination of all parts.

10.2.2 Alternative arrangements will be specially considered.

10.3 Dynamic balancing

10.3.1 All rotors are to be dynamically balanced on final assembly to the Surveyor's satisfaction.

10.4 Overspeed test

10.4.1 All fully bladed rotor sections and impeller/inducer wheels are to be overspeed-tested for three minutes at either 20 per cent above the maximum permissible speed at room temperature or 10 per cent above the maximum permissible speed at the normal working temperature.

10.5 Mechanical running test

10.5.1 Turbo-chargers are to be given a mechanical running test of 20 minutes, duration at the maximum permissible speed.

10.5.2 Upon application, with details of an historical audit covering previous testing of turbochargers manufactured under an approved quality assurance scheme, consideration will be given to confining the test outlined in 10.5.1 to a representative sample of turbochargers.

Section 11
Mass produced engines

11.1 Definition

11.1.1 Mass produced engines, for main and auxiliary purposes, are defined as those which are produced under the following criteria:

(a) In quantity under strict quality control of material and parts, according to a quality assurance scheme acceptable to LR.
(b) By the use of jigs and automatic machine tools designed to machine parts to specified tolerances for interchangeability, and which are verified on a regular inspection basis.
(c) By assembly with parts taken from stock and requiring little or no fitting.
(d) With bench tests carried out on individual assembled engines according to a specified programme.
(e) With appraisal by final examination of engines selected at random after workshop testing.

11.1.2 Castings, forgings and other parts for use in mass produced engines are also to be produced by methods similar to those given in 11.1.1(a), (b) and (c), with appropriate inspection.

11.1.3 Pressure testing of components is to comply with 9.1.1.

11.1.4 The specification of a mass produced engine is to define the limits of manufacture of all component parts. The total production output is to be certified by the manufacturer and verified as may be required by LR, in accordance with the agreed manufacturer's quality assurance scheme, *see* 11.1.1(a).

11.2 Procedure for approval of mass produced engines

11.2.1 The procedure outlined in 11.2.2 to 11.2.5 applies to the inspection and certification of mass produced oil engines having a bore not exceeding 300 mm.

11.2.2 For the approval of a mass produced engine type, the manufacturer is to submit:

(a) The plans and particulars required by 1.1 for assessment.
(b) The information required by 3.2 for assessment.
(c) A list of subcontractors for main parts.
(d) Procedures for the configuring of control, alarm monitoring and safety systems during engine commissioning.

11.2.3 The manufacturer is to supply full information regarding the manufacturing processes and quality control procedures applied in the workshops. The information is to address the following:

(a) Organisation of quality control systems.
(b) Recording of quality control operations.
(c) Qualification and independence of personnel in charge of quality control.

11.2.4 A running type test of at least 100 hours' duration is to be carried out on an engine chosen from the production line. The type testing is to comply with 11.5.

11.2.5 LR reserves the right to limit the duration of validity of approval of a mass produced engine. LR is to be informed, without delay, of any change in the design of the engine, including changes to the software and control, alarm monitoring or safety systems, in the manufacturing or quality control processes, in the selection of materials or in the list of subcontractors for main parts.

11.3 Continuous review of production

11.3.1 LR Surveyors are to be provided free access to the manufacturer's workshops and to the quality control files.

11.3.2 The control of production, which is subject to survey, is to include the following:
(a) Inspection and testing records are to be maintained to the satisfaction of the Surveyor.
(b) The system for identification of parts is to be in accordance with recognised practice, and acceptable to LR.
(c) The manufacturer is to provide full information about the quality control of the parts supplied by subcontractors for which certification may be required. LR reserves the right to apply direct and individual inspection procedures for parts supplied by subcontractors when deemed necessary.
(d) At the request of an attending LR Surveyor, a workshop test may be required for an individual engine.

11.4 Compliance and inspection certificate

11.4.1 Each engine which is to be installed on a unit classed by LR is to be supplied with a statement certifying that the engine is identical to the one which underwent the tests specified in 11.2.4, and state the test and inspection results. The statement is to be made on a form agreed with LR. Each statement is to include the identification number which appears on the engine. A copy of this statement is to be submitted to LR.

11.4.2 The certificate is to include reference to the manufacturer's procedures to be followed during commissioning for configuring control, alarm monitoring and safety systems for multi-purpose engines or other engine types that require parameters and settings to be adjusted for the intended application.

11.5 Type test conditions

11.5.1 The requirements in this Section are applicable to the type testing of mass produced internal combustion engines where the manufacturer has requested approval. Omission or simplification of the type test requirements will be considered by LR for engines of an established type on application by the manufacturer.

11.5.2 The engine to be tested is to be selected from the production line and agreed by LR.

11.5.3 The type tests are to be conducted with the engine control systems operational in the approved configuration, *see* 1.1.4 and 1.1.5. Configuration management documents are to be reviewed at testing for validity and referenced in the type test report.

11.5.4 The duration and programme of type tests is to include the following:
(a) 80 h at rated output.
(b) 8 h at 110 per cent overload.
(c) 10 h at varying partial loads (25 per cent, 50 per cent, 75 per cent and 90 per cent of rated output).
(d) 2 h at maximum intermittent loads.
(e) Starting tests.
(f) Reverse running of direct reversing engines.
(g) Testing of speed governor.
(h) Testing of overspeed device.
(j) Testing of lubricating oil system failure alarm device.
(k) Testing of the engine with turbocharger out of action when applicable.
(l) Testing of minimum speed for main propulsion engines and the idling speed for auxiliary engines.

11.5.5 The type tests in 11.5.4 at the required outputs are to be combined together in working cycles for the whole duration within the limits indicated. *See also* 11.5.11 and 11.5.12.

11.5.6 The overload testing required by 11.5.4 is to be carried out with the following conditions:
(a) 110 per cent of rated power at 103 per cent revolutions per minute for engines directly driving propellers.
(b) 110 per cent of rated power at 100 per cent revolutions per minute for engines driving electrical generators or for other auxiliary purposes.

11.5.7 For prototype engines, the duration and programme of tests are to be specially agreed between the manufacturer and LR.

11.5.8 As far as practicable during type testing, the following particulars are to be continuously recorded:
(a) Ambient air temperature.
(b) Ambient air pressure.
(c) Atmospheric humidity.
(d) External cooling water temperature.
(e) Fuel and lubrication oil characteristics.

11.5.9 In addition to the particulars stated in 11.5.8 and as far as practicable, the following are also to be continuously measured and recorded:
(a) Engine revolutions per minute.
(b) Brake power.
(c) Torque.
(d) Maximum combustion pressure.
(e) Indicator pressure diagrams where practicable.
(f) Exhaust smoke (with an approved smoke meter).
(g) Lubricating oil pressure and temperature.
(h) Exhaust gas temperature in exhaust manifold, and, where facilities are available, from each cylinder.

(j) For turbocharged engines:
- Turbocharger revolutions per minute.
- Air temperature and pressures before and after turbo-blower and charge cooler.
- Exhaust gas temperature and pressures before and after the turbine.
- The cooling water inlet temperature to the charge air cooler.

11.5.10 After the type test, the main parts and especially those subject to wear are to be dismantled for examination by LR Surveyors.

11.5.11 For engines that are required to be approved for different purposes (multi-purpose engines), and that have different performances profiles and control, alarm monitoring and safety systems configurations for each purpose, the programme and duration of test is to be modified to cover the whole range of the engine performance, taking into account the most severe conditions and intended purpose(s).

11.5.12 The rated output for which the engine is to be tested is the output corresponding to that declared by the manufacturer and agreed by LR, i.e., actual maximum power which the engine is capable of delivering continuously between the normal maintenance intervals stated by the manufacturer at the rated speed and under the stated ambient conditions.

■ *Section 12*
Mass produced turbo-chargers

12.1 Application

12.1.1 The following procedure applies to the inspection of exhaust driven turbo-chargers which are manufactured on the basis of mass production methods similar to 11.1, as applicable, and for which the maker has requested approval.

12.2 Procedure for approval of mass produced turbo-chargers

12.2.1 The procedure outlined in 12.2.2 to 12.2.5 applies to the inspection and certification of mass produced turbochargers when a simplified method of inspection has been requested by the manufacturers.

12.2.2 For the approval of a mass produced turbocharger, the manufacturer is to submit, in addition to the plans and particulars required by 10.1.1, a list of main current suppliers and subcontractors for rotating parts and an operation and maintenance manual.

12.2.3 The manufacturer will supply full information regarding the material and quality control system used in the organisation as well as the inspection methods, the way of recording and proposed frequency, and the method of material testing of important parts.

12.2.4 A type test, *see* 10.2, is to be carried out on a standard unit taken from the assembly line and is to be witnessed by the Surveyor. The performance data which may have to be verified are to be made available at the time of the type test. For manufacturers who have facilities for testing the turbo-charger unit on an engine for which the turbo-charger is intended, substitution of the hot running test by a test run of one hour's duration at overload (110 per cent of the rated output) may be considered.

12.2.5 LR reserves the right to limit the duration of validity of approval of a mass produced turbo-charger. LR is to be informed, without delay, of any change in the design of the turbo-charger, in the manufacturing or control processes, in the selection of materials or in the list of subcontractors for main parts.

12.3 Continuous inspection of individual units

12.3.1 LR Surveyors are to be provided with free access to the manufacturer's workshop to inspect at random the quality control measures and to witness the tests required by 12.3.3 to 12.3.7 as deemed necessary, and to have free access to all control records and subcontractor's certificates.

12.3.2 Each individual unit is to be tested in accordance with 12.3.4 to 12.3.7 by the maker, who is to issue a final certificate.

12.3.3 Rotating parts of the turbo-charger blower are to be marked for easy identification with the appropriate certificate.

12.3.4 Material tests of the rotating parts are to be carried out by the maker or his subcontractor in accordance with the requirements of the Rules for Materials, as applicable. The relevant certificate is to be produced and filed to the satisfaction of the Surveyor.

12.3.5 Pressure tests are to be carried out in accordance with Table 2.9.1. Special consideration will be given where design or testing features may require modification of the test requirements.

12.3.6 Dynamic balancing and overspeed tests are to be carried out, *see* 10.3 and 10.4, in accordance with the approved procedure for quality control. If each forged wheel is individually controlled by an approved non-destructive examination method, then no overspeed test may be required except for wheels of the test unit.

12.3.7 A mechanical running test, *see* 10.5, is to be carried out. The duration of the running test may be reduced to 10 minutes, provided that the manufacturer is able to verify the distribution of defects established during the running tests on the basis of a sufficient number of tested turbo-chargers. For manufacturers who have facilities in their works for testing the turbo-chargers on an engine for which the turbochargers are intended, the bench test may be replaced by a test run of 20 minutes at overload (110 per cent of the rated output) on this engine.

12.4 Compliance and certificate

12.4.1 For every turbo-charger unit liable to be installed on an engine intended for a unit classed by LR, the manufacturer is to supply a statement certifying that the turbo-charger is identical with one that underwent the tests specified in 12.2.4 and that prescribed tests were carried out. Results of these tests are to be also stated. This statement is to be made on a form agreed with LR and a copy is to be sent to LR. Each statement must have a number which is to appear on the turbo-charger.

■ *Section 13*
Type testing procedure for crankcase explosion relief valves

13.1 Scope

13.1.1 To specify type tests and identify standard test conditions using methane gas and air mixture to demonstrate that LR requirements are satisfied for crankcase explosion relief valves intended to be fitted to engines and gear cases.

13.1.2 The test procedure is only applicable to explosion relief valves fitted with flame arresters. Where internal oil wetting of a flame arrester is a design feature of an explosion relief valve, alternative testing arrangements that demonstrate compliance with these requirements may be proposed by the manufacturer. The alternative testing arrangements are to be submitted to LR for approval.

13.2 Purpose

13.2.1 The purpose of type testing crankcase explosion relief valves is fourfold:

(a) To verify the effectiveness of the flame arrester.
(b) To verify that the valve closes after an explosion.
(c) To verify that the valve is gas/air tight after an explosion.
(d) To establish the level of over-pressure protection provided by the valve.

13.3 Test facilities

13.3.1 Test houses carrying out type testing of crankcase explosion relief valves are to meet the following requirements:

(a) The test houses where testing is carried out are to be accredited to a National or International Standard for the testing of explosion protection devices such as ISO/IEC 17025.
(b) The test facilities are to be acceptable to LR.
(c) The test facilities are to be equipped so that they can perform and record explosion testing in accordance with this procedure.
(d) The test facilities are to have equipment for controlling and measuring a methane gas in air concentration within a test vessel to an accuracy of ±0,1 per cent.
(e) The test facilities are to be capable of effective point located ignition of a methane gas in air mixture.
(f) The pressure measuring equipment is to be capable of measuring the pressure in the test vessel in at least two positions, one at the valve and the other at the test vessel centre. The measuring arrangements are to be capable of measuring and recording the pressure changes throughout an explosion test at a frequency recognising the speed of events during an explosion. The result of each test is to be documented by electronic recording and by recording with a heat sensitive camera.
(g) The test vessel for explosion testing is to have documented dimensions. The dimensions are to be such that the vessel is not pipe-like with the distance between dished ends being not more than 2,5 times the diameter. The internal volume of the test vessel is to include any standpipe arrangements.
(h) The test vessel is to be provided with a flange, located centrally at one end at 90 degrees to the vessel's longitudinal axis for mounting the explosion relief valve. The test vessel is to be arranged in an orientation consistent with how the valve will be installed in service, i.e., in the vertical plane or the horizontal plane.
(j) A circular flat plate is to be provided for fitting between the pressure vessel flange and valve to be tested with the following dimensions:
    (i) Outside diameter of 2 times the outer diameter of the valve top cover.
    (ii) Internal bore having the same internal diameter as the valve to be tested.
(k) The test vessel is to have connections for measuring the methane in air mixture at the top and bottom.
(l) The test vessel is to be provided with a means of fitting an ignition source at a position as specified in 13.4.3.
(m) The test vessel volume is to be, as far as practicable, related to the size and capability of the relief valve to be tested. In general, the volume is to correspond to the requirement in 6.3.1 for the free area of explosion relief valve to be not less than 115 cm^2/m^3 of crankcase gross volume, e.g., the testing of a valve having 1150 cm^2 of free area would require a test vessel with a volume of 10 m^3. The following is to apply:
    (i) Where the free area of relief valves is greater than 115 cm^2/m^3 of the crankcase gross volume, the volume of the test vessel is to be consistent with the design ratio.
    (ii) In no case is the volume of the test vessel to vary by more than ±15 per cent from the design cm^2/m^3 volume ratio.

13.4 Explosion test process

13.4.1 All explosion tests to verify the functionality of crankcase explosion relief valves are to be carried out using an air and methane mixture with a volumetric methane concentration of 9,5 per cent ±0,5 per cent. The pressure in the test vessel is to be not less than atmospheric and is not to exceed the opening pressure of the relief valve.

13.4.2 The concentration of methane in the test vessel is to be measured at the top and bottom of the vessel and these concentrations are not to differ by more than 0,5 per cent.

13.4.3 The ignition of the methane and air mixture is to be made at the centreline of the test vessel at a position approximately one third of the height or length of the test vessel opposite to where the valve is mounted.

13.4.4 The ignition is to be made using a maximum 100 joule explosive charge.

13.5 Valves to be tested

13.5.1 The valves used for type testing (including testing specified in 13.5.3) are to be selected from the manufacturer's normal production line for such valves by the LR Surveyor witnessing the tests.

13.5.2 For approval of a specific valve size, three valves are to be tested in accordance with 13.5.3 and 13.6. For a series of valves, *see* 13.8.

13.5.3 The valves selected for type testing are to have been previously tested at the manufacturer's works to demonstrate that the opening pressure is in accordance with the specification within a tolerance of ±20 per cent and that the valve is airtight at a pressure below the opening pressure for at least 30 seconds. This test is to verify that the valve is airtight following assembly at the manufacturer's works and that the valve begins to open at the required pressure, demonstrating that the correct spring has been fitted.

13.5.4 The type testing of valves is to recognise the orientation in which they are intended to be installed on the engine or gear case. Three valves of each size are to be tested for each intended installation orientation, i.e. in the vertical and/or horizontal positions.

13.6 Method

13.6.1 The following requirements are to be satisfied at explosion testing:

(a) The explosion testing is to be witnessed by a LR Surveyor.
(b) Where valves are to be installed on an engine or gear case with shielding arrangements to deflect the emission of explosion combustion products, the valves are to be tested with the shielding arrangements fitted.
(c) Successive explosion testing to establish a valve's functionality is to be carried out as quickly as possible during stable weather conditions.
(d) The pressure rise and decay during all explosion testing is to be recorded.
(e) The external condition of the valves is to be monitored during each test for indication of any flame release by electronic recording and heat sensitive camera.

13.6.2 The explosion testing is to be in three stages for each valve that is required to be approved as being type tested.

13.6.3 **Stage 1**. Two explosion tests are to be carried out in the test vessel with the circular plate as specified in 13.3.1(j) fitted and the opening in the plate covered by a 0,05 mm thick polythene film. These tests establish a reference pressure level for determination of the capability of a relief valve in terms of pressure rise in the test vessel, *see* 13.7.1(f).

13.6.4 **Stage 2**:

(a) Two explosion tests are to be carried out on three different valves of the same size. Each valve is to be mounted in the orientation for which approval is sought, i.e., in the vertical or horizontal position with the circular plate described in 13.3.1(j) located between the valve and pressure vessel mounting flange.
(b) The first of the two tests on each valve is to be carried out with a 0,05 mm thick polythene bag, having a minimum diameter of three times the diameter of the circular plate and volume not less than 30 per cent of the test vessel, enclosing the valve and circular plate. Before carrying out the explosion test the polythene bag is to be empty of air. The polythene bag is required to provide a readily visible means of assessing whether there is flame transmission through the relief valve following an explosion. During the test, the explosion pressure will open the valve and some unburned methane/air mixture will be collected in the polythene bag. When the flame reaches the flame arrester and if there is flame transmission through the flame arrester, the methane/air mixture in the bag will be ignited and this will be visible.
(c) Provided that the first explosion test successfully demonstrated that there was no indication of combustion outside the flame arrester and there are no signs of damage to the flame arrester or valve, a second explosion test without the polythene bag arrangement is to be carried out as quickly as possible after the first test. During the second explosion test, the valve is to be visually monitored for any indication of combustion outside the flame arrester and electronic records are to be kept for subsequent analysis. The second test is required to demonstrate that the valve can still function in the event of a secondary crankcase explosion.
(d) After each explosion, the test vessel is to be maintained in the closed condition for at least 10 seconds to enable the tightness of the valve to be ascertained. The tightness of the valve can be verified during the test from the pressure/time records or by a separate test after completing the second explosion test.

13.6.5 **Stage 3**. Carry out two further explosion tests as described in Stage 1. These further tests are required to provide an average baseline value for assessment of pressure rise, recognising that the test vessel ambient conditions may have changed during the testing of the explosion relief valves in Stage 2.

13.7 Assessment and records

13.7.1 For the purposes of verifying compliance with the requirements of this Section, the assessment and records of the valves used for explosion testing is to address the following:

(a) The valves to be tested are to have evidence of appraisal/approval by LR, *see also* 13.5.1.

(b) The designation, dimensions and characteristics of the valves to be tested are to be recorded. This is to include the free area of the valve and of the flame arrester and the amount of valve lift at 0,2 bar.

(c) The test vessel volume is to be determined and recorded.

(d) For acceptance of the functioning of the flame arrester, there is not to be any indication of flame or combustion outside the valve during an explosion test.

(e) The pressure rise and decay during an explosion is to be recorded, with indication of the pressure variation showing the maximum overpressure and steady under-pressure in the test vessel during testing. The pressure variation is to be recorded at two points in the pressure vessel.

(f) The effect of an explosion relief valve in terms of pressure rise following an explosion is ascertained from maximum pressures recorded at the centre of the test vessel during the three stages. The pressure rise within the test vessel due to the installation of a relief valve is the difference between average pressure of the four explosions from Stages 1 and 3 and the average of the first tests on the three valves in Stage 2. The pressure rise is not to exceed the limit specified by the manufacturer.

(g) The valve tightness is to be ascertained by verifying from the records at the time of testing that an under-pressure of at least 0,3 bar is held by the test vessel for at least 10 seconds following an explosion. This test is to verify that the valve has effectively closed and is reasonably gas-tight following dynamic operation during an explosion.

(h) After each explosion test in Stage 2, the external condition of the flame arrester is to be examined for signs of serious damage and/or deformation that may affect the operation of the valve.

(j) After completing the explosion tests, the valves are to be dismantled and the condition of all components ascertained and documented. In particular, any indication of valve sticking or uneven opening that may affect the operation of the valve is to be noted. Photographic records of the valve condition are to be taken and included in the report.

13.8 Design series qualification

13.8.1 The qualification of quenching devices to prevent the passage of flame can be evaluated for other similar devices of identical type where one device has been tested and found satisfactory.

13.8.2 The quenching ability of a flame arrester depends on the total mass of quenching lamellas/mesh. Provided the materials, thickness of materials, length of lamellas/thickness of mesh layer and the quenching gaps are the same, then the same quenching ability can be qualified for different sizes of flame arresters, subject to (a) and (b) being satisfied.

(a) $$\frac{n_1}{n_2} = \sqrt{\frac{S_1}{S_2}}$$

(b) $$\frac{A_1}{A_2} = \frac{S_1}{S_2}$$

where

n_1 = total depth of flame arrester corresponding to the number of lamellas of size 1 quenching device for a valve with a relief area equal to S_1

n_2 = total depth of flame arrester corresponding to the number of lamellas of size 2 quenching device for a valve with a relief area equal to S_2

A_1 = free area of quenching device for a valve with a relief area equal to S_1

A_2 = free area of quenching device for a valve with a relief area equal to S_2.

13.8.3 The qualification of explosion relief valves of larger sizes than that which has been previously satisfactorily tested in accordance with 13.6 and 13.7 can be evaluated where valves are of identical type and have identical features of construction subject to the following:

(a) The free area of a larger valve does not exceed three times +5 per cent that of the valve that has been satisfactorily tested.

(b) One valve of the largest size, subject to (a), requiring qualification is subject to satisfactory testing required by 13.5.3 and 13.6.4 except that a single valve will be accepted in 13.6.4(a) and the volume of the test vessel is not to be less than one third of the volume required by 13.3.1(m).

(c) The assessment and records are to be in accordance with 13.7, noting that 13.7.1(f) will only be applicable to Stage 2 for a single valve.

13.8.4 The qualification of explosion relief valves of smaller sizes than that which has been previously satisfactorily tested in accordance with 13.6 and 13.7 can be evaluated where valves are of identical type and have identical features of construction subject to the following:

(a) The free area of a smaller valve is not less than one third of that of the valve that has been satisfactorily tested.

(b) One valve of the smallest size, subject to (a), requiring qualification is subject to satisfactory testing required by 13.5.3 and 13.6.4 except that a single valve will be accepted in 13.6.4(a) and the volume of the test vessel is not to be more than the volume required by 13.3.1(m).

(c) The assessment and records are to be in accordance with 13.7, noting that 13.7.1(f) will only be applicable to Stage 2 for a single valve.

13.9 The report

13.9.1 The test house is to deliver a full report that includes the following information and documents:
(a) Test specification.
(b) Details of test pressure vessel and valves tested.
(c) The orientation in which the valve was tested, (vertical or horizontal position).
(d) Methane in air concentration for each test.
(e) Ignition source.
(f) Pressure curves for each test.
(g) Electronic recordings of each valve test.
(h) The assessment and records stated in 13.7.

13.10 Approval

13.10.1 The approval of an explosion relief valve is at the discretion of LR, based on the appraisal of plans and particulars and the test facility's report of the results of type testing.

■ *Section 14* Type testing procedure for crankcase oil mist detection and alarm equipment

14.1 Scope

14.1.1 To specify the tests required to demonstrate that crankcase oil mist detection and alarm equipment intended to be fitted to diesel engines satisfies LR requirements.

14.1.2 This test procedure is also applicable to oil mist detection and alarm arrangements intended for gear cases.

14.2 Purpose

14.2.1 The purpose of type testing crankcase oil mist detection and alarm equipment is seven fold:
(a) To verify the functionality of the system.
(b) To verify the effectiveness of the oil mist detectors.
(c) To verify the accuracy of oil mist detectors.
(d) To verify the alarm set points.
(e) To verify time delays between oil mist leaving the source and alarm activation.
(f) To verify functional failure detection.
(g) To verify the influence of optical obscuration on detection.

14.3 Test facilities

14.3.1 Test houses carrying out type testing of crankcase detection and alarm equipment are to satisfy the following criteria:
(a) A full range of facilities for carrying out the environmental and functionality tests required by this procedure shall be available and be acceptable to LR.
(b) The test house that verifies the functionality of the equipment is to be equipped so that it can control, measure and record oil mist concentration levels in terms of mg/l to an accuracy of ±10 per cent in accordance with this procedure.

14.4 Equipment testing

14.4.1 The range of tests is to include the following for the alarm/monitoring panel:
(a) Functional tests described in 14.5.
(b) Electrical power supply failure test.
(c) Power supply variation test.
(d) Dry heat test.
(e) Damp heat test.
(f) Vibration test.
(g) EMC test.
(h) Insulation resistance test.
(j) High voltage test.
(k) Static and dynamic inclinations, if moving parts are contained.

14.4.2 The range of tests is to include the following for the detectors:
(a) Functional tests described in 14.5.
(b) Electrical power supply failure test.
(c) Power supply variation test.
(d) Dry heat test.
(e) Damp heat test.
(f) Vibration test.
(g) EMC test.
(h) Insulation resistance test.
(j) High voltage test.
(k) Static and dynamic inclinations.

14.5 Functional tests

14.5.1 All tests to verify the functionality of crankcase oil mist detection and alarm equipment are to be carried out in accordance with 14.5.2 to 14.5.6 with an oil mist concentration in air, known in terms of mg/l to an accuracy of ±10 per cent.

14.5.2 The concentration of oil mist in the test chamber is to be measured in the top and bottom of the chamber and these concentrations are not to differ by more than 10 per cent. *See* 14.7.2(a).

14.5.3 The oil mist monitoring arrangements are to be capable of detecting oil mist in air concentrations of between 0 and 10 per cent of the lower explosive limit (LEL), which corresponds to an oil mist concentration of approximately 50 mg/l (13 per cent oil-air mixture) or between 0 and a percentage corresponding to a level not less than twice the maximum oil mist concentration alarm set point.

14.5.4 The alarm set point for oil mist concentration in air is to provide an alarm at a maximum setting corresponding to not more than 5 per cent of the LEL or approximately 2,5 mg/l.

14.5.5 Where alarm set points can be altered, the means of adjustment and indication of set points are to be verified against the equipment manufacturer's instructions.

14.5.6 Where oil mist is drawn into a detector via piping arrangements, the time delay between the sample leaving the crankcase and operation of the alarm is to be determined for the longest and shortest lengths of pipes recommended by the manufacturer. The pipe arrangements are to be in accordance with the manufacturer's instructions/ recommendations.

14.5.7 Detector equipment that is in contact with the crankcase atmosphere and may be exposed to oil splash and spray from engine lubricating oil is to be tested to demonstrate that openings do not occlude or become blocked under continuous oil splash or spray conditions. Testing is to be in accordance with arrangements proposed by the manufacturer and agreed by LR.

14.5.8 Detector equipment may be exposed to water vapour from the crankcase atmosphere which may affect the sensitivity of the equipment, it is to be demonstrated that exposure to such conditions will not affect the functional operation of the detector equipment. Where exposure to water vapour and/or water condensation has been identified as a possible source of equipment malfunctioning, testing is to demonstrate that any mitigating arrangements such as heating are effective. Testing is to be in accordance with arrangements proposed by the manufacturer and agreed by LR. This testing is in addition to that required by 14.4.2(e) and is concerned with the effects of condensation caused by the detection equipment being at a lower temperature than the crankcase atmosphere.

14.6 Detectors and alarm equipment to be tested

14.6.1 The detectors and alarm equipment selected for the type testing are to be selected from the manufacturer's normal production line by the LR Surveyor witnessing the tests.

14.6.2 Two detectors are to be tested. One is to be tested in the clean condition and the other in a condition representing the maximum level of lens obscuration specified by the manufacturer.

14.7 Method

14.7.1 The requirements of 14.7 are to be satisfied at type testing.

14.7.2 Oil mist generation is to satisfy the following:

(a) Oil mist is to be generated with suitable equipment using an SAE 80 monograde mineral oil or equivalent and supplied to a test chamber having a volume of not less than 1 m^3. The oil mist produced is to have a maximum droplet size of 5 μm. The oil droplet size is to be checked using the sedimentation method.

(b) The oil mist concentrations used are to be ascertained by the gravimetric deterministic method or equivalent. For this test, the gravimetric deterministic method is a process where the difference in weight of a 0,8 μm pore size membrane filter is ascertained from weighing the filter before and after drawing 1 litre of oil mist through the filter from the oil mist test chamber. The oil mist chamber is to be fitted with a recirculating fan.

(c) Samples of oil mist are to be taken at regular intervals and the results plotted against the oil mist detector output. The oil mist detector is to be located adjacent to where the oil mist samples are drawn off.

(d) The results of a gravimetric analysis are considered invalid and are to be rejected if the resultant calibration curve has an increasing gradient with respect to the oil mist detection reading. This situation occurs when insufficient time has been allowed for the oil mist to become homogeneous. Single results that are more than 10 per cent below the calibration curve are to be rejected. This situation occurs when the integrity of the filter unit has been compromised and not all of the oil is collected on the filter paper.

(e) The filters require to be weighed to a precision of 0,1 mg and the volume of air/oil mist sampled to 10 ml.

14.7.3 The testing is to be witnessed by an LR Surveyor where type testing approval is required by LR.

14.7.4 Oil mist detection equipment is to be tested in the orientation (vertical, horizontal or inclined) in which it is intended to be installed on an engine or gear case as specified by the equipment manufacturer.

14.7.5 Type testing is to be carried out for each type of oil mist detection and alarm equipment for which a manufacturer seeks LR approval. Where sensitivity levels can be adjusted, testing is to be carried out at the extreme and mid-point level settings.

14.8 Assessment

14.8.1 Assessment of oil mist detection equipment devices after testing is to address the following:

(a) The equipment to be tested is to have evidence of design appraisal/approval by LR, *See also* 14.6.1.

(b) Details of the detection equipment to be tested are to be recorded, such as name of manufacturer, type designation, oil mist concentration assessment capability and alarm settings.

(c) After completing the tests, the detection equipment is to be examined and the condition of all components ascertained and documented. Photographic records of the monitoring equipment condition are to be taken and included in the report.

14.9 Design series qualification

14.9.1 The approval of one type of detection equipment may be used to qualify other devices having identical construction details. Proposals are to be submitted for consideration.

14.10 The report

14.10.1 The test house is to provide a full report which includes the following information and documents:
(a) Test specification.
(b) Details of equipment tested.
(c) Results of tests.

14.11 Acceptance

14.11.1 Acceptance of crankcase oil mist detection equipment is at the discretion of LR, based on the appraisal of plans and particulars and the test house report of the results of type testing.

14.11.2 The following information is to be submitted to LR for acceptance of oil mist detection equipment and alarm arrangements:
(a) Description of oil mist detection equipment and system including alarms.
(b) Copy of the test house report identified in 14.10.
(c) Schematic layout of engine oil mist detection arrangements showing location of detectors/sensors and piping arrangements and dimensions.
(d) Maintenance and test manual which is to include the following information:
- Intended use of equipment and its operation.
- Functionality tests to demonstrate that the equipment is operational and that any faults can be identified and corrective actions notified.
- Maintenance routines and spare parts recommendations.
- Limit setting and instructions for safe limit levels.
- Where necessary, details of configurations in which the equipment is and is not to be used.

■ *Section 15* Electronically controlled engines

15.1 Scope

15.1.1 The requirements of this Section are applicable to engines for propulsion, auxiliary or emergency power purposes with programmable electronic systems implemented and used to control fuel injection timing and duration, and which may also control combustion air or exhaust systems. The requirements of this Section also apply to programmable electronic systems used to control other functions (e.g., starting and control air, cylinder lubrication etc.) where essential for the operation of the engine.

15.1.2 These engines may be of the slow, medium or highspeed type. They generally have no direct camshaft driven fuel systems, but have common rail fuel/hydraulic arrangements and may have hydraulic actuating systems for the functioning of the exhaust systems.

15.1.3 The operation of these engines relies on the effective monitoring of a number of parameters such as crank angle, engine speed, temperatures and pressures using programmable electronic systems to provide the services essential for the operation of the engine such as fuel injection, air inlet, exhaust and speed control.

15.1.4 Details of proposals to deviate from the requirements of this Section are to be submitted and will be considered on the basis of a technical justification produced by the Enginebuilder.

15.1.5 Each engine is to be configured for the specified performance and is to satisfy the relevant requirements for propulsion, auxiliary or emergency engines.

15.1.6 During the life of the engine details of any proposed changes to control, alarm, monitoring or safety systems which may affect safety and the reliable operation of the engine are to be submitted to LR for approval.

15.2 Plans and particulars

15.2.1 In addition to the plans and particulars required by Section 1, the following information is to be submitted:
(a) A general overview of the operating principles, supported by schematics explaining the functionality of individual systems and sub-systems. The information is to relate to the engine capability and functionality under defined operating and emergency conditions such as recovery from a failure or malfunction, with particular reference to the functioning of programmable electronic systems and any sub-systems. The information is also to indicate if the engine has different modes of operation, such as to limit exhaust gas emissions and/or to run under an economic fuel consumption mode or any other mode that is electronically controlled.
(b) Operating manuals which describe the particulars of each system and, together with maintenance instructions, include reference to the functioning of sub-systems.
(c) A risk-based analysis of the mechanical, pressure containing, electrical, electronic and programmable electronic systems and arrangements that support the operation of the engine. The analysis is to demonstrate that suitable risk mitigation has been achieved in accordance with 15.3.
(d) Details of hydraulic systems for actuation of sub-systems (fuel injection or exhaust), to include details of the design/construction of pipes, pumps, valves, accumulators and the control of valves/pumps. Details of pump drive arrangements are also to be included.
(e) Quality plan for sourcing, design, installation and testing of all components used in the oil fuel and hydraulic oil systems installed with the engine for engine operation.
(f) Fatigue analysis for all high pressure oil fuel and hydraulic oil piping arrangements required for engine operation where failure of the pipe or its connection or a component would be the cause of engine unavailability. The analysis is to concentrate on high pressure components and sub-systems and recognise the pressures and fluctuating stresses that the pipe system may be subject to in normal service.

(g) Evidence of type testing of the engine with the programmable electronic system, or a proposed test plan at the engine builders with the programmable electronic system functioning, to verify the functionality and behaviour under normal operating and fault conditions of the programmable electronic control system.
(h) Schedule of testing at enginebuilders, pre-sea trial commissioning and sea trials. The test schedules are to identify all modes of engine operation and the sea trials are to include typical port manoeuvres under the intended engine operating modes. The schedule is to include:
    (i) testing and trials to demonstrate that the engine is capable of operating as described in (a);
    (ii) tests to verify that the response of the complete mechanical, hydraulic, electrical and electronic system is as predicted for the intended operational modes; and
    (iii) testing required to verify the conclusions of the risk based analysis.

The scope of these tests is to be agreed with LR.

15.2.2 In addition to the applicable plans and particulars required by Pt 6, Ch 1,1.2.3 to 1.2.7, the following information for control, alarm, monitoring and safety systems relating to the operation of an electronically controlled engine is to be submitted:
(a) Engine configuration details , *see* 15.5.2.
(b) Software quality plans, including configuration management documents.
(c) Software safety evidence.
(d) Software assessment inspection report.

15.3 Risk-based analysis

15.3.1 An analysis is to be carried out in accordance with relevant Standards acceptable to LR to demonstrate compliance with the applicable requirements of this sub-Section, appropriate to the engine application. The analysis is to be a risk-based consideration of engine operation and unit and personnel safety, and is to demonstrate adequate risk mitigation through fault tolerance and/or reliability in accordance with the specified criteria in 15.3.2 to 15.3.4 relevant to the engine application.

15.3.2 For units with a single main propulsion engine, a Failure Mode and Effects Analysis (FMEA), or alternative recognised analysis of system reliability, is to be carried out and is to demonstrate that an electronic control system failure:
(a) will not result in the loss of the ability to provide the services essential for the operation of the engine, *see* Pt 6, Ch 1,2.5.8 and 2.12.2 of the Rules for Ships;
(b) will not affect the normal operation of the services essential for the operation of the engine other than those services dependent upon the failed part, *see* Pt 6, Ch 1,2.13.4 and 2.13.5 of the Rules for Ships; and
(c) will not leave either the engine, or any equipment or machinery associated with the engine, or the unit in an unsafe condition, *see* Pt 6, Ch 1,2.3.12, 2.4.6, 2.5.4, 2.10.3, 2.10.4 and 2.13.5 of the Rules for Ships.

15.3.3 A risk-based analysis is to be carried out for:
(a) main engines on units with multiple main engines or other means of providing propulsion power; and/or
(b) auxiliary engines intended to drive electric generators forming the unit's main source of electrical power or otherwise providing power for essential services. The analysis is to demonstrate that adequate hazard mitigation has been incorporated in electronically controlled engine systems or the overall unit installation with respect to personnel safety and providing propulsion power and/or power for essential services for the safety of the unit. Arrangements satisfying the criteria of 15.3.2(a) to (c) will also be acceptable.

15.3.4 For engines for emergency power purposes, a risk-based analysis is to be carried out to demonstrate that the design incorporates adequate hazard mitigation such that the likelihood of an electronic control system failure resulting in the loss of the ability to provide emergency power when required has been reduced to a level considered acceptable by LR and that means are provided to detect failures and permit personnel to restore engine availability to operate on demand. Failures which would result in engine failure and/or damage or loss of availability are to be identified and the report is to include documentation of:
(a) component reliability evidence;
(b) failure detection and alarms; and
(c) failure response required to restore engine availability and maintain personnel safety.

15.3.5 The risk-based analysis report is to:
(a) Identify the standards used for analysis and system design.
(b) Identify the engine, its purpose and the associated objectives of the analysis.
(c) Identify any assumptions made in the analysis.
(d) Identify the equipment, system or sub-system, mode of operation and the equipment.
(e) Identify potential failure modes and their causes.
(f) Evaluate the local effects (e.g., fuel injection failure) and the effects on the system as a whole (e.g., loss of propulsion power) of each failure mode.
(g) Identify measures for reducing the risks associated with each failure mode (e.g. system design, failure detection and alarms, redundancy, quality control procedures for sourcing, manufacture and testing, etc.).
(h) Identify trials and testing necessary to prove conclusions.

15.3.6 At sub-system level it is acceptable to consider failure of equipment items and their functions, e.g. failure of a pump to produce flow or pressure head. It is not required that the failure of components within that pump be analysed, and failure need only be dealt with as a cause of failure of the pump.

15.4 Oil fuel and hydraulic oil systems

15.4.1 Oil fuel and hydraulic oil piping systems arrangements are to comply with Chapters 2, 11, 12, 13 and 14 as applicable.

15.4.2 Where pumps are essential for engine operation, no fewer than two oil fuel and two hydraulic oil pressure pumps are to be provided for their respective service and arranged such that failure of one pump does not render the other inoperative. Each oil fuel pump and hydraulic oil pump is to be capable of supplying the quantity of oil for engine operation at its maximum continuous rating and arranged ready for immediate use.

15.4.3 The oil fuel pressure piping between the oil fuel high pressure pumps and the fuel injectors is to be protected with a jacketed piping system capable of containing oil fuel leakage from a high pressure pipe failure.

15.4.4 The hydraulic oil pressure piping between the high pressure hydraulic pumps and hydraulic actuators is to be protected with a jacketed piping system capable of containing hydraulic oil leakage from a high pressure pipe failure.

15.4.5 Accumulators and associated high pressure piping are to be designed, manufactured and tested in accordance with a standard applicable to the maximum pressure and temperature rating of the system.

15.4.6 All valves, cocks and screwed connections are to be of a type tested type applicable to the maximum service conditions anticipated in normal service.

15.4.7 Isolating valves and cocks are to be located as near as practicable to the equipment to be isolated. All valves forming part of the oil fuel and hydraulic oil installation are to be capable of being controlled from readily accessible positions above the working platform.

15.4.8 High pressure oil fuel and high pressure hydraulic oil piping systems are to be provided with high pressure alarms with set points that do not exceed the system design pressures.

15.4.9 High pressure oil fuel and high pressure hydraulic piping systems are to be provided with suitable relief valves on any part of the system that can be isolated and in which pressure can be generated. The settings of the relief valves are not to exceed the design pressures. The valves are to be of adequate size and so arranged as to avoid an undue rise in pressure above the design pressures.

15.4.10 Equipment fitted for monitoring pressures and temperatures in the high pressure oil fuel and high pressure hydraulic oil systems is to comply with a recognised Standard suitable to the anticipated vibration and temperature conditions.

15.4.11 A fatigue analysis is to be carried out in accordance with a standard applicable to the system under consideration and all anticipated pressure, pulsation and vibration loads are to be addressed. The analysis is to demonstrate that the design and arrangements are such that the likelihood of failure is as low as reasonably practicable. The analysis is to identify all assumptions made and standards to be applied during manufacture and testing of the system. Any potential weak points which may develop due to incorrect construction or assembly are also to be identified.

15.4.12 For high pressure oil-containing and mechanical power transmission systems, the quality plan for sourcing, design, installation and testing of components is to address the following issues:

(a) Design and manufacturing standard(s) applied.
(b) Materials used for construction of key components and their sources.
(c) Details of the quality control system applied during manufacture and testing.
(d) Details of type approval, type testing or approved type status assigned to the machinery or equipment.
(e) Details of installation and testing recommendations for the machinery or equipment.

15.5 Control engineering systems

15.5.1 Control, alarm, monitoring, safety and programmable electronic systems are to comply with Pt 6, Ch 1 as applicable.

15.5.2 The engine control, alarm monitoring and safety systems are to be configured to comply with the relevant requirements (e.g., operating profile, alarms, shut-downs, etc.) of this Chapter and Pt 6, Ch 1 for an engine for main, auxiliary or emergency power purposes. Details of the engine configuration are to be submitted for consideration identifying:

(a) Local and remote means to carry out system configuration.
(b) Enginebuilder procedures for undertaking configuring.
(c) Roles and responsibilities for configuration (e.g., Enginebuilder, engine packager, system integrator or other nominated party) with accompanying schedule.
(d) Configurable settings and parameters (including those not to be modified from a default value).
(e) Configuration for propulsion, auxiliary or emergency engine application. Configuration records are to be maintained and are to be made available to the Surveyor at testing and trials and on request in accordance with Pt 6, Ch 1,1.4 and 7.1.3 of the Rules for Ships.

15.6 Software

15.6.1 Software lifecycle activities are to be carried out in accordance with an acceptable quality management system, *see* Pt 6, Ch 1,2.10.20, 2.13.2 and 2.13.8 of the Rules for Ships.

15.6.2 Appropriate safety related processes, methods, techniques and tools are to be applied to software development and maintenance by the Enginebuilder. Selection and application of techniques and measures in accordance with Annex A of IEC 61508-3, *Functional safety of electrical/ electronic/programmable electronic systems: Software requirements*, or other relevant Standards or Codes acceptable to LR, will generally be acceptable.

15.6.3 To demonstrate compliance with 15.6.1 and 15.6.2:

(a) software quality plans and safety evidence are to be submitted for consideration, *see* 15.2.2(b) and (c); and

(b) an assessment inspection of the Enginebuilder's completed development is to be carried out by LR. The inspection is to be tailored to verify application of the Standards and Codes used in software safety assurance accepted by LR.

Section 16
Alarms and safeguards for emergency diesel engines

16.1 Application

16.1.1 These requirements apply to emergency diesel engines required to be immediately available in an emergency and capable of being controlled remotely or automatically.

16.2 Alarms and safeguards

16.2.1 Alarm and safety systems are to comply with the requirements of Pt 6, Ch 1.

16.2.2 Alarms and safeguards are to be fitted in accordance with Table 2.16.1.

16.2.3 The safety and alarm systems are to be designed to 'fail safe'. The characteristics of the 'fail safe' operation are to be evaluated on the basis not only of the system and its associated machinery, but also the complete installation, as well as the unit.

16.3.4 Regardless of the engine output, if shut-downs additional to those specified in Table 2.16.1 are provided except for the overspeed shut-down, they are to be automatically overridden when the engine is in automatic or remote control mode during navigation.

16.3.5 Grouped alarms of at least those items listed in Table 2.16.1 are to be arranged on the bridge.

16.3.6 In addition to the fuel oil control from outside the space, a local means of engine shut-down is to be provided.

16.3.7 Local indications of at least those items listed in Table 2.16.1 are to be provided within the same space as the diesel engines and are to remain operational in the event of failure of the alarm and safety systems.

Table 2.16.1 Alarms and safeguards for emergency diesel engines

Item	Alarm	Alarm	Note
Emergency Diesel Engine	≥ 220 kW	<220 kW	
Fuel oil leakage from pressure pipes	Leakage	Leakage	*See* 7.1.2
Lubricating oil temperature	High	—	—
Lubricating oil pressure	Low	Low	—
Oil mist concentration in crankcase	High	—	See Note
Coolant pressure or flow	Low	—	—
Coolant Temperature (can be air)	High	High	—
Overspeed	High	—	Automatic shutdown

NOTE
For engines having a power of more than 2250 kW or a cylinder bore of more than 300 mm.

Section 17
General requirements

17.1 Turning gear

17.1.1 Turning gear is to be provided for all engines to facilitate operating and maintenance regimes as required by the manufacturer.

17.1.2 The turning gear for all main propulsion engines is to be power-driven and, if electric, is to be continuously rated at a value to ensure protection to the weakest part of the machinery.

17.1.3 The turning gear for auxiliary engines may be hand operated (manual) except where this is not practicable, in which case the provision of 17.1.2 is to be complied with.

17.1.4 The turning gear for all engines is to be fitted with safety interlocks which prevent engine operation when engaged, *see* Ch 1,3.10. Indication of engaged/not engaged is to be provided at all start positions.

17.1.5 The remote control device of power-driven turning gear is to be so designed that power is removed from the turning gear when the operating switch is released.

17.1.6 Means are to be provided to secure the turning gear when disengaged.

17.1.7 Overload protection arrangements are to be provided to prevent damage to the electric motor and the turning gear train.

Section 18
Program for trials of diesel engines to assess operational capability

18.1 Works trials (acceptance test)

18.1.1 Diesel engines which are to be subjected to trials on the test bed at the manufacturer's works and under attendance by the Surveyor(s) are to be tested in accordance with the scope of works trials specified in 18.1.2 to 18.1.10. The scope of the trials is to be agreed between the LR Surveyor and the manufacturer prior to testing. At the discretion of the Surveyor, the scope of the trials may be extended, depending on the engine application.

18.1.2 For electronically controlled engines:
(a) works tests in accordance with 15.2.1(h); and
(b) verification of engine configuration, *see* 15.5.2, and that the approved software quality plans, including the software configuration management process, are being applied.

18.1.3 For all stages of the works trials, the pertaining operation values are to be measured and recorded by the engine manufacturer. All results are to be compiled in an acceptance protocol to be issued by the engine manufacturer.

18.1.4 In each case given in Table 2.18.1, all measurements conducted at the various load points shall be carried out at steady operating conditions. The readings for 100 per cent power (rated power at rated speed) are to be taken twice at an interval of at least 30 minutes.

18.1.5 The data to be measured and recorded, when testing the engine at various load points, are to include all necessary parameters for the engine operation. The crankshaft deflection is to be checked when this check is required by the manufacturer during the operating life of the engine. Crankshaft deflection measurements are to be taken before (cold condition) and after (hot condition) works acceptance trials.

18.1.6 Checks of components to be presented for inspection after the works trials are left to the discretion of the Surveyor.

18.1.7 The Surveyor may require that after the trials the fuel delivery system is restricted so as to limit the engines to run at not more than 100 per cent power. The setting of the restriction is to be made applicable to the intended fuel. Any restriction settings, and other changes to the engine's fuel injection equipment required for operation on special fuels, are to be recorded and included by the engine manufacturer.

18.1.8 For the duration of the acceptance test, no interventions or adjustments will be made to the machinery under test.

18.1.9 The testing of exhaust gas emissions is to comply with MARPOL as applicable.

18.1.10 For all stages that the engine is to be tested and where no duration is specified in Table 2.18.1, the load point is to be maintained for a sufficient period to allow pertaining values to be measured and recorded when the engine has achieved a steady operating condition.

18.2 Trials

18.2.1 After the conclusion of the running-in programme prescribed by the engine manufacturer, engines are to undergo trials as specified in Table 2.18.2. The scope of the trials is to be agreed between the LR Surveyor and the Builder prior to testing.

18.2.2 Engines driving generators or important auxiliaries are to be subjected to an operational test for at least 4 hours. During the test, the set concerned is required to operate at its rated power for an extended period. It is to be demonstrated that the engine is capable of supplying 100 per cent of its rated power, and in the case of unit's generating sets, account shall be taken of the times needed to actuate the generator's overload protection system.

18.2.3 In addition to 18.2.2, for engines driving generators for electric propulsion motors as well as auxiliaries, an operational test is to be carried out of at least 4 hours, duration at a load which corresponds to 100 per cent of the electric propulsion motor(s) rated power. The astern/ahead manoeuvring capability of the propulsion system is to be demonstrated.

18.2.4 Trials are to include demonstration of engine control, monitoring, alarm and safety system operation to confirm that they have been provided, installed and configured as intended and in accordance with the relevant requirements for main, auxiliary or emergency engines.

18.2.5 For electronically controlled engines:
(a) tests in accordance with 15.2.1(h); and
(b) verification of engine configuration, *see* 15.5.2, and that the approved software quality plans, including the software configuration management process, are being applied .

18.2.6 The suitability of an engine to burn residual or other special fuels is to be demonstrated, if the machinery installation is arranged to burn such fuels in service. *See also* Pt 6, Ch 1,7.2.1 of the Rules for Ships.

18.2.7 At the discretion of the attending Surveyor, the scope of the trials may be expanded in consideration of special operating conditions, such as towing, trawling, etc.

Table 2.18.1 Scope of works trials for diesel engines

Main engines driving propellers and waterjets		
Trial condition	Duration	Note
100% power (rated power) at rated engine speed, *R*	≥ 60 minutes	After having reached steady conditions
110% power at engine speed corresponding to 1,032*R*	30–45 minutes	After having reached steady conditions (1)
90% (or maximum continuous power), 75%, 50% and 25%	—	Powers in accordance with the nominal propeller curve
Starting and reversing manoeuvres	—	—
Testing of governor and independent overspeed protective device	—	*See* 5.2
Shut-down device	—	*See* 5.4
Engines driving generators		
Trial condition	Duration	Note
100% power (rated power) at rated engine speed, *R*	≥ 50 minutes	After having reached steady conditions (2)
110% power	30 minutes	After having reached steady conditions (2) (3)
75%, 50% and 25% power and idle run	—	(2)
Start-up tests	—	—
Testing of governor and independent overspeed protective device	—	*See* 5.3
Shut-down device	—	*See* 5.4

NOTES
1. After running on the test bed, the fuel delivery system of main engines is normally to be so adjusted that overload power cannot be given in service.
2. The test is to be performed at rated speed with a constant governor setting.
3. After running on the test bed, the fuel delivery system of diesel engines driving generators must be adjusted such that overload (110%) power can be given in service after installation on board, so that the governing characteristics including the activation of generator protective devices can be fulfilled at all times.

Table 2.18.2 Scope of trials for diesel engines

Main engines driving fixed-pitch propellers (1) (2)		
Trial condition	Duration	Note
At rated engine speed, *R*	≥ 4 hours	—
At engine speed corresponding to normal continuous power	≥ 2 hours	—
At engine speed corresponding to 1,032**R*	30 minutes	Where the engine adjustment permits, *see* 18.1.7
At minimum on-load speed	—	—
Starting and reversing manoeuvres	—	*See* Section 8
In reverse direction of propeller rotation during the dock or sea trials at a minimum engine speed of 0,7**R*	10 minutes	—
Control monitoring, alarms and safety systems	—	Operation to be demonstrated
Where imposed, test to ensure engine can pass safely through barred speed range	—	—
Single engine driving a generator for propulsion only		
Trial condition	Duration	Note
100% power (rated propulsion power), see 18.2.3	≥ 4 hours	(3) (4)
At normal continuous propulsion power	≥ 2 hours	(3) (4)
110% power (rated propulsion power)	30 minutes	—
In reverse direction of propeller rotation at a minimum speed of 70% of the nominal propeller speed	10 minutes	(3) (4)
Starting manoeuvres	—	—
Control monitoring, alarms and safety systems	—	Operation to be demonstrated

NOTES
1. For main propulsion engines driving controllable pitch propellers, waterjets or reversing gears, the tests for main engines driving fixed-pitch propellers apply as appropriate.
2. Controllable pitch propellers are to be tested with various propeller pitches.
3. The tests are to be performed at rated speed with a constant governor setting.
4. Tests are to be based on the rated electrical powers of the electric propulsion motors.

■ *Cross-references*

The pumping arrangements, including cooling water and lubricating oil systems, are to comply with the requirements of Chapter 14.

For spare gear, *see* Ch 1,7.

■ *Scope*

The requirements of this Chapter are applicable to steam turbines for main propulsion and also, where powers exceed 110 kW (150 shp), to those for essential auxiliary services.

■ *Section 1* Plans and particulars

1.1 Plans

1.1.1 The following plans are to be submitted for consideration, together with particulars of materials, maximum shaft powers and revolutions per minute, *see* Ch 1,3.3. The pressures and temperatures applicable at maximum shaft power and under the emergency conditions of 5.2 are to be stated or indicated on the plans.

- General arrangement.
- Sectional assembly.
- Rotors and couplings.
- Casings.

1.1.2 For the emergency conditions of 5.3, full particulars of the means proposed for emergency propulsion are to be submitted.

1.1.3 Where rotors and castings are of welded construction, details of the welded joints are also to be submitted for consideration.

1.1.4 In general, plans for auxiliary turbines need not be submitted.

■ *Section 2* Materials

2.1 General

2.1.1 In the selection of materials, consideration is to be given to their creep strength, corrosion resistance and scaling properties at working temperatures to ensure satisfactory performance and long life under service conditions.

2.1.2 Grey cast iron is not to be used for temperatures exceeding 260°C.

2.2 Materials for forgings

2.2.1 Turbine rotors and discs are to be of forged steel. For carbon and carbon-manganese steel forgings, the specified minimum tensile strength is to be selected within the limits of 400 and 600 N/mm^2 (41 and 61 kgf/mm^2). For alloy steel rotor forgings, the specified minimum tensile strength is to be selected within the limits of 500 and 800 N/mm^2 (51 and 82 kgf/mm^2). For discs and other alloy steel forgings, the specified minimum tensile strength is to be selected within the limits of 500 and 1000 N/mm^2 (51 and 102 kgf/mm^2).

2.2.2 For alloy steels, details of the proposed chemical composition, heat treatment and mechanical properties are to be submitted for approval.

2.2.3 When it is proposed to use material of higher tensile strength, full details are to be submitted for approval.

■ *Section 3* Design and construction

3.1 General

3.1.1 In the design and arrangement of turbine machinery, adequate provision is to be made for the relative thermal expansion of the various turbine parts, and special attention is to be given to minimising casing and rotor distortion under all operating conditions.

3.1.2 Turbine bearings are to be so disposed and supported that lubrication is not adversely affected by heat flow from adjacent hot parts of the turbine. Effective means are to be provided for intercepting oil leakage and preventing oil from reaching high temperature glands and casings and steam pipes. Drainage openings and drain pipes from oil baffle pockets are to be sufficiently large to prevent excessive accumulation and leakage of oil.

3.2 Welded components

3.2.1 Turbine rotors, cylinders and associated components fabricated by means of welding will be considered for acceptance if constructed by firms whose works are properly equipped to undertake welding to equivalent standards, for rotors and cylinders respectively, to those required by the Rules for Class 1 and Class 2/1 welded pressure vessels, *see* Ch 17, Sections 1 to 7.

3.2.2 Welding is to be carried out in accordance with the requirements of Ch 13,4 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials) using welding procedures and welders that have been qualified in accordance with Chapter 12 of the Rules for Materials.

3.2.3 Before work is commenced, manufacturers are to submit for consideration details of proposed welding procedures and their proposals for routine examination of joints by non-destructive means.

3.2.4 Materials used in the construction of turbine rotors, cylinders, diaphragms, condensers, etc., are to be of welding quality.

3.2.5 Where it is proposed to construct rotors from two or more forged components joined by welding, full details of the chemical composition, mechanical properties and heat treatment of the materials, together with particulars of the welding consumables, an outline of the welding procedure, method of fabrication and heat treatment, are to be submitted for consideration.

3.2.6 Joints in rotors and major joints in cylinders are to be designed as full-strength welds and for complete fusion of the joint.

3.2.7 Adequate preheating is to be employed for mild steel cylinders and components and where the metal thickness exceeds 44 mm, and for all low alloy steel cylinders and components and for any part where necessitated by joint restraint.

3.2.8 Stress relief heat treatment is to be applied to all cylinders and associated components on completion of the welding of all joints and attached structures. For details of stress relief procedure, temperature and duration, *see* Ch 13,4.11 of the Rules for Materials.

3.2.9 For all welded components, weld procedure tests are to be in accordance with Ch 12,2.7 of the Rules for Materials.

3.2.10 Production weld tests are to be performed according to the requirements of Ch 13,4.5 of the Rules for Materials.

3.3 Stress raisers

3.3.1 Smooth fillets are to be provided at abrupt changes of section of rotors, spindles, discs, blade roots and tenons. The rivet holes in blade shrouds are to be rounded and radiused on top and bottom surfaces, and tenons are to be radiused at their junction with blade tips. Balancing holes in discs are to be well rounded and polished.

3.3.2 Surveyors are to be satisfied as to the workmanship and riveting of blades to shroud bands, and that the blade tenons are free from cracks, particularly with high tensile blade material. Test samples are to be sectioned and examined, and pull-off tests made if considered necessary by the Surveyors.

3.4 Shrunk-on rotor discs

3.4.1 Main turbine rotor discs fitted by shrinking are to be secured with keys, dowels or other approved means.

3.5 Vibration

3.5.1 Care is to be taken in the design and manufacture of turbine rotors, rotor discs and blades to ensure freedom from undue vibration within the operating speed range. Consideration of blade vibration should include the effect of centrifugal force, blade root fixing, metal temperature and disc flexibility where appropriate.

3.5.2 For the vibration and alignment of main propulsion systems formed by the turbines geared to the line shafting, *see* Chapter 8.

3.6 External influences

3.6.1 Pipes and ducts connected to turbine casings are to be so designed that no excessive thrust loads or moments are applied by them to the turbines. Gratings and any fittings in way of sliding feet or flexible-plate supports are to be so arranged that casing expansion is not restricted. Where main turbine seatings incorporate a tank structure, consideration is to be given to the temperature variation of the tank in service to ensure that turbine alignment will not be adversely affected.

3.7 Steam supply and water system

3.7.1 In the arrangement of the gland sealing system, the pipes are to be made self-draining and every precaution is to be taken against the possibility of condensed steam entering the glands and turbines. The steam supply to the gland sealing system is to be fitted with an effective drain trap. In the air ejector re-circulating water system, the connection to the condenser is to be so located that water cannot impinge on the L.P. rotor or casing.

3.8 Turning gear

3.8.1 Turning gear is to be provided for all turbines to facilitate operating and maintenance regimes as required by the manufacturer.

3.8.2 The turning gear for all propulsion turbines is to be power-driven and, if electric, is to be continuously rated.

3.8.3 The turning gear for auxiliary turbines may be hand operated (manual) except where this is not practicable, in which case the provision of 3.8.2 is to be complied with.

3.8.4 The turning gear for all turbines is to be fitted with safety interlocks which prevent steam valve actuation for turbine operation when engaged, *see* Ch 1,3.9. Indication of engaged/not engaged is to be provided at all start positions.

3.8.5 The remote control device of power-driven turning gear is to be so designed that power is removed from the turning gear when the operating switch is released.

3.8.6 Means are to be provided to secure the turning gear when disengaged.

■ *Section 4* Safety arrangements

4.1 Overspeed protective devices

4.1.1 An overspeed protective device is to be provided for main and auxiliary turbines to shut off the steam automatically and prevent the maximum designed speed being exceeded by more than 15 per cent.

4.1.2 Where two or more turbines of a compound main turbine installation are separately coupled to the same main gear wheel, and one overspeed protective device is provided, this is to be fitted to the L.P. ahead turbine. Hand trip gear for shutting off the steam in an emergency is to be provided at the manoeuvring platform.

4.2 Speed governors

4.2.1 Where a turbine installation incorporates a reverse gear, electric transmission or reversible propeller, a speed governor, in addition to, or in combination with, the overspeed protective device, is to be fitted, and is to be capable of controlling the speed of the unloaded turbine without bringing the overspeed protective device into action.

4.2.2 Auxiliary turbines intended for driving electric generators are to be fitted with speed governors which, with fixed setting, are to control the speed within 10 per cent momentary variation and 5 per cent permanent variation when full load is suddenly taken off or put on. The permanent speed variations of alternating current machines intended for parallel operations are to equalise within a tolerance of ±0,5 per cent.

4.3 Low vacuum and overpressure protective devices

4.3.1 In order to provide a warning of excessive pressure to personnel in the vicinity of the exhaust ends of main turbines, sentinel relief valves are to be provided at the exhaust ends or other approved positions. The relief valve discharge outlets are to be visible and suitably guarded if necessary. Where a low vacuum cut-out device is provided, the sentinel relief valve at the L.P. exhaust may be omitted.

4.3.2 In order to provide a warning of excessive pressure to personnel in the vicinity of the exhaust ends of auxiliary turbines, sentinel relief valves are to be provided at the exhaust ends. The relief valve discharge outlets are to be visible and suitably guarded if necessary. Low vacuum or overpressure cut-out devices, as appropriate, are also to be provided for auxiliary turbines not installed with their own condensers.

4.4 Bled steam connections

4.4.1 Non-return or other means, which will prevent steam and water returning to the turbines, are to be fitted in bled steam connections.

4.5 Steam strainers

4.5.1 Efficient steam strainers are to be provided close to the inlets to ahead and astern high pressure turbines, or alternatively at the inlets to the manoeuvring valves.

■ *Section 5* Emergency arrangements

5.1 Lubricating oil failure

5.1.1 Arrangements are to be made for the steam to the ahead propulsion turbines to be automatically shut off in the event of failure of the lubricating oil pressure; however, steam is to be made available at the astern turbine for braking purposes in such an emergency, *see* Chapter 14 for emergency oil supply.

5.1.2 Auxiliary turbine arrangements are to be such that steam supply is automatically shut off in the event of failure of the lubricating oil pressure.

5.2 Single screw units

5.2.1 In single screw units fitted with cross compound steam turbine installations in which two or more turbines are separately coupled to the same main gear wheel, the arrangements are to be such as to enable safe navigation when the steam supply is led direct to the L.P. turbine and either the H.P or L.P. turbine can exhaust direct to the condenser. Adequate arrangements and controls are to be provided for these emergency operating conditions so that the pressure and temperature of the steam will not exceed that which the turbines and condenser can safely withstand.

5.2.2 The necessary pipes and valves or fittings for these arrangements are to be readily available and properly marked. A fit up test of all combinations of pipes and valves is to be performed prior to the first sea trials.

5.2.3 The permissible power/speeds of the operating turbines(s) when operating without one of the turbines (all combinations) is to be specified and information provided on board.

5.2.4 The operation of the turbines under emergency conditions is to be assessed for the potential influence on shaft alignment and gear teeth loading conditions.

5.3 Single main boiler

5.3.1 Units intended for unrestricted service, fitted with steam turbines and having a single main boiler, are to be provided with means to ensure emergency propulsion in the event of failure of the main boiler.

■ *Section 6* Tests and equipment

6.1 Stability testing of turbine rotors

6.1.1 All solid forged H.P. turbine rotors intended for main propulsion service where the inlet steam temperature exceeds 400°C are to be subjected to at least one thermal stability test. This requirement is also applicable to rotors constructed from two or more forged components joined by welding. The test may be carried out at the forge or turbine builders' works:

(a) after heat treatment and rough machining of the forging; or
(b) after final machining; or
(c) after final machining and blading of the rotor.

The stabilising test temperature is to be not less than 28°C above the maximum steam temperature to which the rotor will be exposed, and not more than the tempering temperature of the rotor material. For details of a recommended test procedure and limits of acceptance, *see* the Rules for Materials. Other test procedures may be adopted if approved.

6.1.2 Where main turbine rotors are subjected to thermal stability tests at both forge and turbine builders' works, the foregoing requirements are applicable to both tests. It is not required that auxiliary turbine rotors be tested for thermal stability, but, if such tests are carried out, the requirement for main turbine rotors will be generally applicable.

6.2 Balancing

6.2.1 All rotors as finished-bladed and complete with half-coupling are to be dynamically balanced to the Surveyor's satisfaction, in a machine of sensitivity appropriate to the size of rotor.

6.3 Hydraulic tests

6.3.1 Manoeuvring valves are to be tested to twice the working pressure. The nozzle boxes of impulse turbines are to be tested to 1,5 times the working pressure.

6.3.2 The cylinders of all turbines are to be tested to 1,5 times the working pressure in the casing, or to 2,0 bar (2,0 kgf/cm^2), whichever is the greater.

6.3.3 For test purposes, the cylinders may be subdivided with temporary diaphragms for distribution of test pressures.

6.3.4 Condensers are to be tested in the steam space to 1,0 bar (1,0 kgf/cm^2). The water space is to be tested to the maximum pressure which the pump can develop at unit's full draught with the discharge valve closed plus 0,7 bar (0,7 kgf/cm^2), with a minimum test pressure of 2,0 bar (2,0 kgf/cm^2). Where the operating conditions are not known, the test pressure is to be not less than 3,4 bar (3,5 kgf/cm^2), *see* Chapter 14.

6.4 Indicators for movement

6.4.1 Indicators for determining the axial position of rotors relative to their casings, and for showing the longitudinal expansion of casings at the sliding feet, if fitted, are to be provided for main turbines. The latter indicators should be fitted at both sides and be readily visible.

6.5 Weardown gauges

6.5.1 Main and auxiliary turbines are to be provided with bridge weardown gauges for testing the alignment of the rotors.

■ *Cross-references*

The pumping arrangements, including cooling water and lubricating oil systems, are to comply with the requirements of Chapters 13 and 14.

For lists of spare gear to be carried, *see* Ch 1,7.

■ *Scope*

The requirements of this Chapter are applicable to gas turbines for main propulsion and also, where powers exceed 110 kW (150 shp), to those for essential auxiliary services. The requirements do not apply to exhaust gas turbo-blowers.

Approval will be in respect of the mechanical integrity of the gas turbine (including gas generator and power turbine), intake and exhaust ducting configuration, acoustic enclosure configuration (where appropriate), fuel, lubricating oil and starter systems, control alarm and monitoring systems and other critical support systems.

Type approval of the gas turbine bare engine will be required as part of the approval process for first of type.

■ *Section 1* General requirements

1.1 Application

1.1.1 This Chapter is to be read in conjunction with Chapter 1 *General Requirements for the Design and Construction of Machinery*, Pt 6, Ch 1 *Control Engineering Systems* and Pt 6, Ch 2 *Electrical Engineering*, of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships).

1.2 Standard reference conditions

1.2.1 Where power, efficiency, heat rate or specific consumption refer to standard conditions (ISO 2314), such conditions are to be:

(a) for the intake air at the compressor flange (compressor intake flare):
- a total pressure of 101,3 kPa;
- an ambient temperature of 15°C;
- a relative humidity of 60 per cent; and

(b) for the exhaust at the turbine exhaust flange (or recuperator outlet):
- a static pressure of 101,3 kPa.

1.3 Power ratings

1.3.1 Where the dimensions of any particular component are determined from shaft power, *P*, in kW, and revolutions per minute, *R*, the values are those defined in Chapter 1.

1.4 Gas turbine type approval

1.4.1 New gas turbine types or developments of existing types are to be type approved in accordance with LR's *Type Approval System Procedure – Test Specification GT04*.

1.4.2 Where a gas turbine type has subsequently proved satisfactory in service with a number of applications, a maximum power uprating of 10 per cent may be considered without a further complete design re-assessment and type test.

1.5 Inclination of vessel

1.5.1 Gas turbines are to operate satisfactorily under the conditions of inclinations as shown in Table 1.3.2, Table 1.3.3 or Table 1.3.4 in Chapter 1, as applicable.

■ *Section 2* Particulars to be submitted

2.1 Plans and information

2.1.1 The following plans are to be submitted for consideration:
- Casings.
- Combustion chambers, intercoolers and heat exchangers.
- Compressor and gas generator rotating components.
- Control engineering systems, *see* Pt 6, Ch 1 of the Rules for Ships.
- Cooling and sealing air arrangements for compressor and gas generator components: Schematic only.
- Cooling water system: Schematic only, where applicable.
- Fuel systems: Schematic only.
- Gas turbine unit acoustic enclosure, if applicable, including ventilation and drainage systems: Schematic only.
- Inlet and exhaust ducting arrangement.
- Lubricating oil systems: Schematic only.
- Nozzles, blades and blade attachments.
- Oil fuel systems: Schematic only.
- Power turbine components.
- Rotors, bearings and couplings.
- Sectional assembly.
- Securing arrangement, including details of resilient mounts, where applicable.
- Starting system: Schematic only.

2.1.2 The following information and calculations, where applicable, are to be submitted:

(a) Operational requirements:
- Proposed field of application and operational limitations.
- Power/speed operational envelope.
- Calculations and information for short-term high power operation.
- Operation and maintenance manuals including the declared lives of critical components and overhaul schedules recommended by the manufacturer.

(b) Calculations of the critical speeds of blade and rotor vibration, giving full details of the basic assumptions, *see also* 4.3.1.

(c) Analysis of the effect of rotor blade release together with details of operating experience, *see also* 4.3.2.

(d) High temperature characteristics of the materials, including (at working temperatures) the associated creep rate and rupture strength for the designed service life, fatigue strength, corrosion resistance and scaling properties.

(e) Material requirements:
- Particulars of heat treatment, including stress relief.
- Material specifications covering the listed components together with details of any surface treatments, non-destructive testing and hydraulic tests.

(f) The most onerous pressures and temperatures to which each component may be subjected are to be indicated on plans or provided as part of the design specification.

(g) Calculations of the steady state stresses, including the effect of stress raisers, etc., in the compressor and turbine rotors and blading at the maximum speed and temperature in service. Such calculations are to indicate the designed service life and be accompanied, where possible, by test results substantiating the limiting criteria.

(h) Details of calculations and tests to establish the service life of other stressed or safety critical components, including bearings, seals, couplings and gearing. Calculations and tests are to take account of all relevant environmental factors including the particular type of service and fuel intended to be used.

(j) Mounting requirements:
- Securing arrangements, including details of resilient mounts.
- Calculations concerning the amplitude and frequency of vibration associated with resilient type mountings.

(k) A Failure Mode and Effects Analysis (FMEA).

(l) Miscellaneous:
- Design standard of intake filtration for water particulate and corrosive marine salts.
- Details of compressor washing system.
- Fuel specification.

2.1.3 Components fabricated by means of welding will be considered for acceptance if constructed by firms whose works are properly equipped to undertake welding of the standards appropriate to the components. Details are to be submitted for consideration.

2.1.4 Before work is commenced, manufacturers are to submit for consideration details of proposed welding procedures and their proposals for routine examination of joints by non-destructive means.

2.1.5 The manufacturer's proposals for testing the gas turbine are to be submitted for consideration and are to include rotor balancing techniques, methods of determining the soundness of pressure casings and heat exchanger tests, *see* Section 1.

■ *Section 3* **Materials**

3.1 Materials for forgings

3.1.1 Details of materials for rotors and discs are to be submitted for approval.

3.2 Material tests and inspection

3.2.1 Components are to be tested in accordance with the relevant requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

3.2.2 For components of novel design, special consideration will be given to the material test and non-destructive testing requirements.

■ *Section 4* **Design and construction**

4.1 General

4.1.1 All parts of compressors, turbines, etc., are to have clearances and fits consistent with adequate provision for the relative thermal expansion of the various components. Provision is to be made to limit the distortion of the casing and rotor under all normal operating conditions.

4.1.2 Where welding is employed for the construction of the wheels, the requirements of Chapters 12 and 13 of the Rules for Materials are complied with.

4.1.3 Gas generator and power turbine bearings are to be so disposed and supported that lubrication is not adversely affected by heat flow from adjacent hot parts. Effective means are to be provided for intercepting oil leakage and preventing oil from reaching high temperature glands and casings.

4.2 Vibration

4.2.1 The design and manufacture of compressor and turbine rotors, rotor discs and rotor blades are to ensure freedom from undue vibration within the full operating speed range. Where critical speeds are found by calculation to occur within the operating speed range, vibration tests may be required in order to verify the calculations, *see also* Chapter 8.

4.2.2 Vibration monitoring is to form an integral part of the gas turbine safety and control system. The vibration monitoring system is to be capable of detecting the out-of-balance of major parts with means being provided to shut down the gas turbine, before an over-critical situation occurs, i.e., multiple rotor blade or disc release.

4.3 Containment

4.3.1 Gas turbines and power turbines are to be designed and installed, so far as is practicable, to contain debris in the event of rotor blade release.

4.3.2 In the event of a major component failure, when the turbine casing may not contain the debris, oil fuel, lubricating oil and other potentially hazardous systems or equipment are, where practicable, to be located outside of the plane of high speed rotating parts. This requirement also applies to fire detection and extinction equipment, *see also* Section 5.

4.3.3 Gas turbine ancillaries containing flammable products are to be segregated or protected from high temperature areas.

4.4 Intake and exhaust ducts

4.4.1 Air intakes are to be designed and located to minimise the possibility of ingestion of harmful objects. Means are also to be provided for detecting and preventing icing up of air intakes.

4.4.2 Suitable intake filtration is to be provided to control the ingestion of water, particulate and corrosive marine salts within the gas turbine manufacturer’s specified limits.

4.4.3 Where an air intake enclosure forms the connection between the unit’s downtake and the gas turbine installation, a suitable alarm function is to be provided to give warning when an unacceptable air intake pressure loss is reached at the air inlet (bellmouth) of the gas turbine.

4.4.4 Intakes are to be designed such that material cannot become detached due to air flow or corrosion. Fixing bolts and fastenings are to be positively locked so that they cannot work loose.

4.4.5 Multi-engine installations are to have separate intakes and exhausts so arranged as to prevent induced circulation through a stopped gas turbine unit.

4.4.6 The arrangement of the exhaust duct is to be such as to prevent, under normal conditions of unit motion and atmospheric conditions, exhaust gases being drawn into machinery spaces, air conditioning systems and intakes.

4.4.7 Where the exhaust is led overboard near the waterline, means are to be provided to prevent water from being siphoned back into the gas turbine. Where the exhaust is cooled by water spray, the exhaust pipes are to be self draining overboard. Erosion/corrosion-resistant shut-off flaps or other devices are to be fitted on the hull side shell or pipe end with suitable arrangements made to prevent water flooding the machinery space.

4.5 External influences

4.5.1 Pipes and ducting connected to casings are to be so designed that they apply no excessive loads or moments to the compressors and turbines.

4.5.2 Platform gratings and fittings in way of the supports are to be so arranged that casing expansion is not restricted.

4.5.3 Where the gas turbine seating incorporates a tank structure, any temperature variation of the tank in service is not adversely to affect the gas generator and power turbine alignment.

4.5.4 For machinery fastening arrangements, including resilient mounting, *see* Chapter 1.

4.6 Corrosive deposits

4.6.1 Means are to be provided for periodic removal of salt deposits and atmospheric contaminants from blading and internal surfaces.

4.7 Acoustic enclosures

4.7.1 Acoustic enclosures, where fitted, are to be provided with an access door, adequate internal lighting and one or more observation windows to allow the viewing of critical parts of the gas turbine.

4.7.2 A suitable ventilation system, designed to maintain all components within their safe working temperature under all operating conditions, is to be provided.

4.7.3 The ventilation system is to be fitted with shut-off flaps arranged to close automatically upon activation of the enclosure’s fire detection and extinguishing system.

4.7.4 Acoustic enclosure fire safety arrangements are to comply with the requirements of Pt 6, Ch 1 of the Rules for Ships and the *International Convention for the Safety of Life at Sea, 1974*, as amended (SOLAS 74), *see also* 8.7.1.

4.8 Thermal insulation

4.8.1 Where surfaces of the gas generator, power turbine and exhaust volute exceed a temperature of 220°C during operation, these are to be suitably insulated and clad to minimise the risk of fire and prevent damage by heat to adjacent components, *see* 5.1.5.

4.9 Welded construction

4.9.1 Welding is to be carried out in accordance with the requirements of Chapter 13 of the Rules for Materials, using welding procedures and welders that have been qualified in accordance with Chapter 12 of the Rules for Materials.

4.9.2 Stress relief heat treatment is to be applied to all cylinders, rotors and associated components on completion of all welding, *see* Chapter 17.

4.10 Turning gear

4.10.1 Gas generator turning gear is to be provided to facilitate operating and maintenance regimes as required by the manufacturer.

4.10.2 The turning gear may be hand operated (manual) except where this is not practicable. If electrically driven, the motor is to be continuously rated.

4.10.3 The turning gear is to be fitted with safety interlocks which prevent engine operation when engaged, *see* Ch 1,3.9. Indication of engaged/not engaged is to be provided at all start positions.

4.10.4 The remote control device of power-driven turning gear is to be so designed that power is removed from the turning gear when the operating switch is released.

4.10.5 If permanently attached, means are to be provided to secure the turning gear when disengaged.

■ *Section 5* Piping systems

5.1 General

5.1.1 Gas turbine piping systems are, in general, to comply with the requirements given in Chapter 12 and Chapter 14, due regard being paid to the particular type of installation. For the burning of compressed natural gas, *see* the *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquefied Gases*.

5.1.2 The materials and/or their surface treatment used for the storage and distribution of oil fuel are to be selected such that they do not introduce contamination, or modify the properties of the fuel.

5.1.3 Corrosion resistant materials are to be used in all fuel pipes between the treatment and combustion systems.

5.1.4 Suitable fuel treatment systems, including filtration and centrifuging, are to be provided to control the level of water and particulate contamination within the engine manufacturer's specified limits.

5.1.5 The gas turbine design and construction are to minimise the possibility of a fire fed by fuel or lubricating oil leaks.

5.1.6 In dual-fuel applications, provision is to be made for automatic isolation of both primary and standby fuel supplies to the engine in the event of a fire.

5.2 Oil fuel systems

5.2.1 Oil fuel arrangements are to comply with the requirements of Chapter 14.

5.2.2 All external high pressure oil fuel delivery lines between the pressure fuel pumps and fuel metering valves are to be protected with a jacketed piping system capable of containing fuel from a high pressure line failure to prevent oil fuel or oil fuel mist from reaching a source of ignition on the engine or its surroundings.

5.2.3 Suitable arrangements are to be made for draining any oil fuel leakage from the protection required by 5.2.2 and to prevent contamination of the lubricating oil by oil fuel. An alarm is to be provided to indicate that leakage is taking place.

5.2.4 At least two filters are to be fitted in the oil fuel supply lines to the gas turbine and be so arranged that any filter may be cleaned without interrupting the supply of filtered oil fuel to the gas turbine.

5.3 Lubricating oil systems

5.3.1 Lubricating oil arrangements are to comply with the requirements of Chapter 14.

5.3.2 Where the lubricating oil for gas turbines is circulated under pressure, provision is to be made for the efficient filtration of the oil. At least two filters are to be fitted in the lubricating oil supply lines to the gas turbine and be so arranged that any filter may be cleaned without interrupting the supply of filtered lubricating oil to the gas turbine.

5.4 Cooling systems

5.4.1 Cooling water arrangements are to comply with the requirements of Chapter 14, where appropriate.

■ *Section 6* Starting arrangements

6.1 General

6.1.1 Equipment for initial starting of gas turbines is to be provided and arranged such that the necessary initial charge of starting air, hydraulic or electrical power can be developed on board the unit without external aid. If, for this purpose, an emergency air compressor or electric generator is required, these units are to be power-driven by manually started oil engines, except in the case of small installations where a hand-operated compressor of approved capacity may be accepted.

6.1.2 Alternatively, other devices of approved type may be accepted as a means of providing the initial start.

6.1.3 Where the integrity of the starting system is susceptible to overspeed conditions, appropriate alarm and/or trip functions are to be provided, *see also* Pt 6, Ch 1 of the Rules for Ships.

6.2 Purging before ignition

6.2.1 Means are to be provided to clear all parts of the gas turbine of the accumulation of oil fuel or for purging gaseous fuel before ignition commences on starting, or recommences after failure to start. The purge is to be of sufficient duration to displace at least three times the volume of the exhaust system.

6.3 Air starting

6.3.1 Where the gas turbine is arranged for air starting, the total air receiver capacity is to be sufficient to provide, without replenishment, no fewer than six consecutive starts. At least two air receivers of approximately equal capacity are to be provided to satisfy the plant air start requirements. For scantlings and fittings of air receivers, *see* Chapter 11.

6.3.2 For multi-engine installations, three consecutive starts per engine are required.

6.4 Electric starting

6.4.1 Where the gas turbine is fitted with electric starters powered from batteries, two batteries are to be fitted. Each battery is to be capable of starting the gas turbine and the combined capacity is to be sufficient without recharging to provide the number of starts required by 6.3.1 or 6.3.2.

6.4.2 The requirements for battery installations are given in Pt 6, Ch 2 of the Rules for Ships.

6.5 Hydraulic starting

6.5.1 Where the gas turbine is arranged for hydraulic starting, the capacity of the power pack is to be sufficient to provide the number of starts of the gas turbine as required by 6.3.1 or 6.3.2.

■ *Section 7* Tests

7.1 Dynamic balancing

7.1.1 All compressor and turbine rotors as finished-bladed and complete with all relevant parts, such as half-couplings, are to be dynamically balanced in accordance with the manufacturer's specification in a machine of sensitivity appropriate to the size of rotor.

7.2 Hydraulic testing

7.2.1 Where design permits, casings are to be tested to a hydraulic pressure equal to 1,5 times the highest pressure in the casing during normal operation, or 1,5 times the pressure during starting, whichever is the higher. For test purposes, if necessary, the casings may be subdivided with temporary diaphragms for distribution of test pressure. Where the operating temperature exceeds 300°C, the test pressure is to be suitably corrected.

7.2.2 Where hydraulic testing is impracticable, 100 per cent non-destructive tests by ultrasonic or radiographic methods are to be carried out on all casing parts with satisfactory results. Where ultrasonic tests have been carried out, the manufacturer is to provide documentary evidence that ultrasonic examination has been carried out by an approved operator and that there were no indications of defects which could be expected to have a prejudicial effect on the operational performance of the gas turbine.

7.2.3 The shell and tube arrangement of intercoolers and heat exchangers are to be tested to 1,5 times their maximum working pressure.

7.3 Overspeed tests

7.3.1 Before installation, it is to be satisfactorily demonstrated that the gas turbine is capable of safe operation for five minutes at five per cent above the nominal setting of the overspeed protective device, or 15 per cent above the maximum design speed, whichever is the higher.

7.3.2 Where it is impracticable to overspeed the complete installation, each compressor and turbine rotor completely bladed and with all relevant parts such as half-couplings, is to be overspeed-tested individually at the appropriate speed.

■ *Section 8* Control, alarm and safety systems

8.1 General

8.1.1 Control alarm and safety systems are to comply with the requirements of Pt 6, Ch 1 of the Rules for Ships.

8.2 Overspeed protection and shut-down system

8.2.1 The gas turbine is to be protected against overspeed by the provision of a suitable device(s) capable of shutting down the gas turbine safely before a dangerous overspeed condition occurs.

8.3 Power turbine inlet over-temperature control

8.3.1 The power turbine is to be protected against overtemperature.

8.4 Flameout

8.4.1 Indication is to be provided for identifying poor combustion from each combustion chamber, flame-out and failure to ignite conditions, *see also* 6.2.1.

8.5 Lubricating oil system

8.5.1 Means are to be provided accurately to determine the pressure and temperature of the lubricating oil supply to the various parts of the gas generator and power turbine, and scavenge oil and return systems to ensure safe operation.

8.5.2 Means are to be provided to ensure that the temperature of the lubrication oil supply is automatically controlled to maintain steady-state conditions throughout the normal operating range of the gas turbine.

8.5.3 Where the oil supply to the power turbine is fed from a separate supply system, similar arrangements to those detailed above are to be provided.

8.6 Hand trip arrangement

8.6.1 Means are to be provided, at both the local and remote control/operating positions, to initiate manually the shut-down of the gas turbine in an emergency.

8.7 Fire detection, alarm and extinguishing systems

8.7.1 The gas turbine installation is to be provided with a fire detection, alarm and extinguishing system. The requirements of Pt 6, Ch 1 and the *International Convention for the Safety of Life at Sea, 1974* as amended (SOLAS 74) are to be complied with.

■ *Scope*

The requirements of this Chapter, except where otherwise stated, are applicable to oil engine gearing for main propulsion purposes and for oil engine gearing for driving auxiliary machinery which is essential for the safety of the unit or for safety of persons on board where the transmitted powers exceed 220 kW (300 shp) for propulsion drives, and 110 kW (150 shp) for auxiliary drives. Alternatively, calculations using the methods defined in ISO 6336 – *Calculation of load capacity of spur and helical gears*, will be considered. In any mesh, the terms pinion and wheel refer to the smaller and larger gear respectively. For turbine gearing the loading factors K_A, $K_{F\alpha}$, $K_{F\beta}$, $K_{H\alpha}$, $K_{H\beta}$ and K_γ will be considered. Bevel gears will be specially considered on the basis of a conversion to equivalent helical gears. For torsional vibration requirements, *see* Ch 8,2.3.

■ *Section 1* **Plans and particulars**

1.1 Gearing plans

1.1.1 Particulars of the gearing are to be submitted with the plans for all propulsion gears and for auxiliary gears where the transmitted power exceeds 110 kW (150 shp), as follows:

(a) Plans and information demonstrating conformance with the applicable Rules and Standards as stated in scope.
(b) Shaft power and revolution for each pinion.
(c) Number of teeth in each gear.
(d) Reference diameters.
(e) Helix angles at reference diameters.
(f) Normal pitches of teeth at reference diameters.
(g) Tip diameters.
(h) Root diameters.
(j) Face widths and gaps, where applicable.
(k) Pressure angles of teeth (normal or transverse) at reference diameters.
(l) Accuracy grade Q in accordance with ISO 1328 or an equivalent Standard.
(m) Surface texture of tooth flanks and roots.
(n) Minimum backlash.
(o) Centre distance.
(p) Basic rack tooth form.
(q) Protuberance and final machining allowance.
(r) Details of post hobbing processes, if any.
(s) Details of tooth flank corrections, if adopted.
(t) Case depth for surface-hardened teeth.
(u) Shrinkage allowance for shrunk-on rims and hubs.
(v) Type of coupling proposed for oil engine applications.

1.2 Material specifications

1.2.1 Specifications for materials of pinions, pinion sleeves, wheel rims, gear wheels, and quill shafts, giving chemical composition, heat treatment and mechanical properties, are to be submitted for approval with the plans of gearing.

1.2.2 Where the teeth of a pinion or gear wheel are to be surface-hardened, i.e., carburised, nitrided, tufftrided or induction-hardened, the proposed specification and details of the procedure are to be submitted for approval.

■ *Section 2* **Materials**

2.1 Material properties

2.1.1 In the selection of materials for pinions and wheels, consideration is to be given to their compatibility in operation. Except in the case of low reduction ratios, for gears of through-hardened steels, provision is also to be made for a hardness differential between pinion teeth and wheel teeth. For this purpose, the specified minimum tensile strength of the wheel rim material is not to be more than 85 per cent of that of the pinion.

2.1.2 For construction that involves welding the requirements of Chapters 12 and 13 of the Rules for Materials, are to be complied with. Where it is intended to weld very high strength materials, the proposals will be subject to special consideration which shall include review of the welding consumables used, preheat levels, weld types and the level of stress to be experienced during service.

2.1.3 Subject to 2.1.1, the specified minimum tensile strength is to be selected within the following limits:

Pinion and pinion sleeves	550 to 1050 N/mm^2 (56 to 107 kgf/mm^2)
Gear wheels and rims	400 to 850 N/mm^2 (41 to 87 kgf/mm^2)

A tensile strength range is also to be specified and is not to exceed 120 N/mm^2 (12 kgf/mm^2) when the specified minimum tensile strength is 600 N/mm^2 (61 kgf/mm^2) or less. For higher strength steels, the range is not to exceed 150 N/mm^2 (15 kgf/mm^2).

2.1.4 Unless otherwise agreed, the full specified minimum tensile strength of the core is to be 800 N/mm^2 (82 kgf/mm^2) for induction-hardened or nitrided gearing and 750 N/mm^2 (76 kgf/mm^2) for carburised gearing.

2.1.5 For nitrided gearing, the full depth of the hardened zone is to be not less than 0,5 mm and the hardness is to be not less than 500 HV for a depth of 0,25 mm.

2.2 Non-destructive tests

2.2.1 An ultrasonic examination is to be carried out on all gear blanks where the finished diameter of the surfaces, where teeth will be cut, is in excess of 200 mm.

2.2.2 Magnetic particle or liquid penetrant examination is to be carried out on all surface-hardened teeth. This examination may also be requested on the finished machined teeth of through-hardened gears.

2.2.3 NDE of welds are to be performed in accordance with the requirements specified in Chapter 13 of the Rules for Materials.

■ *Section 3* Design

3.1 Symbols

3.1.1 For the purposes of this Chapter the following symbols apply:

a = centre distance, in mm
b = face width, in mm
d = reference diameter, in mm
d_a = tip diameter, in mm
d_{an} = virtual tip diameter, in mm
d_b = base diameter, in mm
d_{bn} = virtual base diameter, in mm
d_{en} = virtual diameter to the highest point of single tooth pair contact, in mm
d_f = root diameter, in mm
d_{fn} = virtual root diameter, in mm
d_n = virtual reference diameter, in mm
d_s = shrink diameter, in mm
d_w = pitch circle diameter, in mm
f_{ma} = tooth flank misalignment due to manufacturing errors, in μm
f_{pb} = maximum base pitch deviation of wheel, in μm
f_{Sh} = tooth flank misalignment due to wheel and pinion deflections, in μm
f_{Sho} = intermediary factor for the determination of f_{Sh}
g_α = length of line of action for external gears, in mm:

$$= 0{,}5\sqrt{(d_{a1}^2 - d_{b1}^2)} + 0{,}5\sqrt{(d_{a2}^2 - d_{b2}^2)} - a \sin\alpha_{tw}$$

for internal gears:

$$= 0{,}5\sqrt{(d_{a1}^2 - d_{b1}^2)} - 0{,}5\sqrt{(d_{a2}^2 - d_{b2}^2)} + a \sin\alpha_{tw}$$

h = total depth of tooth, in mm
h_{ao} = basic rack addendum of tool, in mm
h_F = bending moment arm for root stress, in mm
h_W = sum of actual tooth addenda of pinion and wheel, in mm
m_n = normal module, in mm
n = rev/min of pinion
q = machining allowances, in mm
q_s = notch parameter
q' = intermediary factor for the determination of C_γ
u = gear ratio = $\dfrac{\text{Number of teeth in wheel}}{\text{Number of teeth in pinion}} \geq 1$
v = linear speed at pitch circle, in m/s
x = addendum modification coefficient
y_α = running in allowance, in μm
y_β = running in allowance, in μm
z = number of teeth
z_n = virtual number of teeth

$$= \frac{z}{\cos^2 \beta_b \cos \beta}$$

C_γ = tooth mesh stiffness (mean total mesh stiffness per unit face width), in N/mm μm
F_t = nominal tangential tooth load, in N

$$= \frac{P}{nd}\ 19{,}098 \times 10^6$$

F_β = total tooth alignment deviation (maximum value specified), in μm
$F_{\beta x}$ = actual longitudinal tooth flank deviation before running in, in μm
$F_{\beta y}$ = actual longitudinal tooth flank deviation after running in, in μm
HV = Vickers hardness number
K_A = application factor
$K_{F\alpha}$ = transverse load distribution factor
$K_{F\beta}$ = longitudinal load distribution factor
$K_{H\alpha}$ = transverse load distribution factor
$K_{H\beta}$ = longitudinal load distribution factor
K_v = dynamic factor
$K_{v\alpha}$ = dynamic factor for spur gears
$K_{v\beta}$ = dynamic factor for helical gears
K_γ = load sharing factor
P = transmitted power, in kW
P_r = radial pressure at shrinkage surface, in N/mm^2
P_{ro} = protuberance of tool, in mm
Q = accuracy grade derived from ISO 1328 – *Cylindrical gears – ISO system of accuracy*
R_a = surface roughness – arithmetical mean deviation (C.L.A.) as determined by an instrument having a minimum wavelength cut-off of 0,8 mm and for a sampling length of 2,5 mm, in μm
S_{pr} = residual undercut left by protuberance in mm
S_{Fmin} = minimum factor of safety for bending stress
S_{Fn} = tooth root chord in the critical section, in mm
S_{Hmin} = minimum factor of safety for Hertzian contact stress
Y_D = design factor
Y_F = tooth form factor
$Y_{R\,rel\,T}$ = relative surface finish factor
Y_S = stress concentration factor
Y_{ST} = stress correction factor
Y_x = size factor
Y_β = helix angle factor
$Y_{\delta\,rel\,T}$ = relative notch sensitivity factor
Z_E = material elasticity factor
Z_H = zone factor
Z_R = surface finish factor
Z_V = velocity factor
Z_X = size factor
Z_β = helix angle factor
Z_ε = contact ratio factor
α_{en} = pressure angle at the highest point of single tooth contact, in degrees
α_n = normal pressure angle at reference diameter, in degrees
α_t = transverse pressure angle at reference diameter, in degrees

α_{tw} = transverse pressure angle at pitch circle diameter, in degrees
α_{Fen} = angle for application of load at the highest point of single tooth contact, in degrees
β = helix angle at reference diameter, in degrees
β_b = helix angle at base diameter, in degrees
γ = intermediary factor for the determination of f_{Sh}
ε_α = transverse contact ratio

$$= \frac{g_\alpha \cos\beta}{\pi\, m_n \cos\alpha_t}$$

$\varepsilon_{\alpha n}$ = virtual transverse contact ratio
ε_β = overlap ratio

$$= \frac{b \sin\beta}{\pi\, m_n}$$

ε_γ = total contact ratio
ρ_{ao} = tip radius of tool, in mm
ρ_c = relative radius of curvature at pitch point, in mm

$$= \frac{a \sin\alpha_{tw}\, u}{\cos\beta_b\,(1+u)^2}$$

ρ_F = tooth root fillet radius at the contact of the 30° tangent, in mm
σ_y = yield or 0,2 per cent proof stress, in N/mm^2
σ_B = ultimate tensile strength, in N/mm^2
σ_F = bending stress at tooth root, in N/mm^2
$\sigma_{F\,lim}$ = endurance limit for bending stress in N/mm^2
σ_{FP} = allowable bending stress at the tooth root, in N/mm^2
σ_H = Hertzian contact stress at the pitch circle, in N/mm^2
$\sigma_{H\,lim}$ = endurance limit for Hertzian contact stress, in N/mm^2
σ_{HP} = allowable Hertzian contact stress, in N/mm^2

Subscript:
$_1$ = pinion
$_2$ = wheel
$_0$ = tool.

3.2 Tooth form

3.2.1 The tooth profile in the transverse section is to be of involute shape, and the roots of the teeth are to be formed with smooth fillets of radii not less than 0,25m_n.

Table 5.3.1 Values of K_A

Main and auxiliary gears	K_A
Main propulsion oil engine reduction gears:	
Hydraulic coupling or equivalent on input	1,10
High elastic coupling on input	1,30
Other coupling	1,50
Auxiliary gears:	
Electric and diesel engine drives with hydraulic coupling or equivalent on input	1,00
Diesel engine drives with high elastic coupling on input	1,20
Diesel engine drives with other couplings	1,40

3.2.2 All sharp edges left on the tips and ends of pinion and wheel teeth after hobbing and finishing are to be removed.

3.3 Tooth loading factors

3.3.1 For values of application factor, K_A, *see* Table 5.3.1.

3.3.2 Load sharing factor, K_γ. The value for K_γ is to be taken as 1,15 for multi-engine drives or split torque arrangements. Otherwise K_γ is to be taken as 1,0. Alternatively, where measured data exists, a derived value will be considered.

3.3.3 Dynamic factor, K_v:

For helical gears with $\varepsilon_\beta \geq 1$:
$K_v = 1 + Q^2 v z_1\, 10^{-5} = K_{v\beta}$

For helical gears with $\varepsilon_\beta < 1$:
$K_v = K_{v\alpha} - \varepsilon_\beta\,(K_{v\alpha} - K_{v\beta})$

For spur gears:
$K_v = 1 + 1{,}8 Q^2 v z_1\, 10^{-5} = K_{v\alpha}$

where $\dfrac{vz_1}{100} > 14$ for helical gears, and

where $\dfrac{vz_1}{100} > 10$ for spur gears the value of K_v will be specially considered.

3.3.4 Longitudinal load distribution factors, $K_{H\beta}$ and $K_{F\beta}$:

$$K_{H\beta} = 1 + \frac{b\, F_{\beta y}\, C_\gamma}{2\, F_t\, K_A\, K_\gamma\, K_v}$$

Calculated values of $K_{H\beta} > 2$ are to be reduced by improved accuracy and helix correction as necessary:

where
$F_{\beta y} = F_{\beta x} - y_\beta$ and
$F_{\beta x} = 1{,}33\, f_{Sh} + f_{ma}$
$f_{ma} = {}^2/_3\, F_\beta$ at the design stage, or
$f_{ma} = {}^1/_3\, F_\beta$ where helix correction has been applied

$f_{Sh} = f_{Sho}\,\dfrac{F_t\, K_A\, K_\gamma\, K_v}{b}$ where

f_{Sho} = $23\gamma 10^{-3}$ µm mm/N for gears without helix correction and without end relief, or
= $16\gamma 10^{-3}$ µm mm/N for gears without helix correction but with end relief, where

$\gamma = \left(\dfrac{b}{d_1}\right)^2$ for single helical and spur gears

$= 3\left(\dfrac{b}{2d_1}\right)^2$ for double helical gears

The following minimum values are applicable, these also being the values where helix correction has been applied:

f_{Sho} = 10×10^{-3} µm mm/N for helical gears, or
= 5×10^{-3} µm mm/N for spur gears

For through-hardened steels and surface-hardened steels running on through-hardened steels:

$y_\beta = \dfrac{320}{\sigma_{H\,lim}}\, F_{\beta x}$ when

$y_\beta \leq \dfrac{12800}{\sigma_{H\,lim}}$ µm, and

For surface-hardened steels, when
$y_\beta = 0{,}15 F_{\beta x}$
$y_\beta \leq 6$ µm
$K_{F\beta} = K_{H\beta}{}^{n}$

where

$$n = \frac{\left(\frac{b}{h}\right)^2}{1 + \frac{b}{h} + \left(\frac{b}{h}\right)^2}$$

NOTES

1. $\frac{b}{h}$ is to be taken as the smaller of $\frac{b_1}{h_1}$ or $\frac{b_2}{h_2}$

2. For double helical gears $\frac{b}{2}$ is to be substituted for b in the equation for n.

3.3.5 Transverse load distribution factors, $K_{H\alpha}$ and $K_{F\alpha}$

$K_{H\alpha} = K_{F\alpha} \geq 1{,}00$

where

$\varepsilon_\gamma \leq 2$

$$K_{H\alpha} = \frac{\varepsilon_\gamma}{2}\left\{0{,}9 + \frac{0{,}4C_\gamma\,(f_{pb} - y_\alpha)\,b}{F_t\,K_A\,K_\gamma\,K_v\,K_{H\beta}}\right\}$$

where

$\varepsilon_\gamma > 2$

$$K_{H\alpha} = 0{,}9 + 0{,}4\sqrt{\frac{2\,(\varepsilon_\gamma - 1)}{\varepsilon_\gamma}}\left\{\frac{C_\gamma\,(f_{pb} - y_\alpha)\,b}{F_t\,K_A\,K_\gamma\,K_v\,K_{H\beta}}\right\}, \text{ but}$$

$$K_{H\alpha} \leq \frac{\varepsilon_\gamma}{\varepsilon_\alpha\,Z_\varepsilon^2} \text{ and}$$

$$K_{F\alpha} \leq \frac{\varepsilon_\gamma}{0{,}25\varepsilon_\gamma + 0{,}75}$$

When tip relief is applied, f_{pb} is to be half of the maximum specified value:

$$y_\alpha = \frac{160}{\sigma_{H\,lim}}\,f_{pb} \text{ for through-hardened steels, when}$$

$$y_\alpha \leq \frac{6400}{\sigma_{H\,lim}}\ \mu\text{m and}$$

$y_\alpha = 0{,}075 f_{pb}$ for surface-hardened steels, when

$y_\alpha \leq 3\,\mu$m

When pinion and wheel are manufactured from different materials:

$$y_\alpha = \frac{y_{\alpha 1} + y_{\alpha 2}}{2}$$

3.3.6 Tooth mesh stiffness, C_γ:

$$C_\gamma = \frac{0{,}8}{q'}\cos\beta\,(0{,}75\varepsilon_a + 0{,}25) \text{ N/mm }\mu\text{m}$$

where

$$q' = 0{,}04723 + \frac{0{,}1551}{z_{n1}} + \frac{0{,}25791}{z_{n2}} - 0{,}00635x_1 - \frac{0{,}11654x_1}{z_{n1}} - 0{,}00193x_2 - \frac{0{,}24188x_2}{z_{n2}} + 0{,}00529x_1^2 + 0{,}00182x_2^2$$

For internal gears $z_{n2} = \infty$

Other calculation methods for C_γ will be specially considered.

3.4 Tooth loading for surface stress

3.4.1 The Hertzian contact stress, σ_H, at the pitch circle is not to exceed the allowable Hertzian contact stress, σ_{HP}.

$$\sigma_H = Z_H\,Z_E\,Z_\varepsilon\,Z_\beta\sqrt{\frac{F_t\,(u+1)}{d_1\,b\,u}\,K_A\,K_\gamma\,K_v\,K_{H\beta}\,K_{H\alpha}} \text{ and}$$

$$\sigma_{HP} = \frac{\sigma_{H\,lim}\,Z_R\,Z_V\,Z_X}{S_{H\,min}} \text{ for the pinion/wheel combination}$$

where

$$Z_H = \sqrt{\frac{2\cos\beta_b\cos\alpha_{tw}}{\cos^2\alpha_t\sin\alpha_{tw}}}$$

$Z_E = 189{,}8$ for steel

$$Z_\varepsilon = \sqrt{\frac{4 - \varepsilon_\alpha}{3}\,(1 - \varepsilon_\beta) + \frac{\varepsilon_\beta}{\varepsilon_\alpha}} \text{ for } \varepsilon_\beta < 1 \text{ and}$$

$$Z_\varepsilon = \sqrt{\frac{1}{\varepsilon_\alpha}} \text{ for } \varepsilon_\beta \geq 1$$

$$Z_\beta = \sqrt{\cos\beta}$$

$$Z_R = \left(\frac{1}{R_a}\right)^{0{,}11} \text{ but } Z_R \leq 1{,}14$$

Where R_a is the surface roughness value of the tooth flanks. When pinion and wheel tooth flanks differ then the larger value of R_a is to be taken.

$$Z_V = 0{,}88 + 0{,}23\left(0{,}8 + \frac{32}{v}\right)^{-0{,}5}$$

For values of Z_X, *see* Table 5.3.2

$\sigma_{H\,lim}$, *see* Table 5.3.3

$S_{H\,lim}$, *see* Table 5.3.4.

Table 5.3.2 Values of Z_x

Pinion heat treatment		Z_x
Carburised and induction-hardened	$m_n \leq 10$ $10 < m_n < 30$ $30 \leq m_n$	1,00 $1{,}05 - 0{,}005m_n$ 0,9
Nitrided	$m_n < 7{,}5$ $7{,}5 < m_n < 30$ $30 \leq m_n$	1,00 $1{,}08 - 0{,}011m_n$ 0,75
Through-hardened	All modules	1,00

Table 5.3.3 Values of endurance limit for Hertzian contact stress, $\sigma_{H\ lim}$

Heat treatment: Pinion	Heat treatment: Wheel	$\sigma_{H\ lim}$ N/mm^2
Through-hardened	Through-hardened	$0{,}46\sigma_{B2} + 255$
Surface-hardened	Through-hardened	$0{,}42\sigma_{B2} + 415$
Carburised, nitrided or induction hardened	Soft bath nitrided (Tufftrided)	1000
Carburised, nitrided or induction-hardened	Induction-hardened	$0{,}88\ HV_2 + 675$
Carburised or nitrided	Nitrided	1300
Carburised	Carburised	1500

Table 5.3.4 Factors of safety

	$S_{H\ min}$	$S_{F\ min}$
Main propulsion gears	1,4	1,8
Auxiliary gears	1,15	1,40

3.5 Tooth loading for bending stress

3.5.1 The bending stress at the tooth root, σ_F is not to exceed the allowable tooth root bending stress σ_{FP}

$$\sigma_F = \frac{F_t}{b\, m_n} Y_F\, Y_S\, Y_\beta\, K_A\, K_\gamma\, K_v\, K_{F\beta}\, K_{F\alpha} \quad \text{N/mm}^2$$

$$\sigma_{FP} = \frac{\sigma_{F\ lim}\, Y_{ST}\, Y_{\delta\ rel\ T}\, Y_{R\ rel\ T}\, Y_x}{S_{F\ min}\, Y_D} \quad \text{N/mm}^2$$

For values of $S_{F\ min}$, *see* Table 5.3.4
$\sigma_{F\ lim}$, *see* Table 5.3.5
Stress correction factor $Y_{ST} = 2$.

Table 5.3.5 Values of endurance limit for bending stress, $\sigma_{F\ lim}$

Heat treatment	$\sigma_{F\ lim}$ N/mm^2
Through-hardened carbon steel	$0{,}09\sigma_B + 150$
Through-hardened alloy steel	$0{,}1\sigma_B + 185$
Soft bath nitrided (Tufftrided)	330
Induction hardened	0,35 HV + 125
Gas nitrided	390
Carburised A	450
Carburised B	410

NOTES
1. A is applicable for Cr Ni Mo carburising steels.
2. B is applicable for other carburising steels.

3.5.2 Tooth form factor, Y_F:

$$Y_F = \frac{6\dfrac{h_F}{m_n}\cos\alpha_{F\ en}}{\left(\dfrac{S_{Fn}}{m_n}\right)^2 \cos\alpha_n}$$

where
h_F, $\alpha_{F\ en}$ and S_{Fn} are shown in Fig. 5.3.1

$$\frac{S_{Fn}}{m_n} = z_n \sin\left(\frac{\pi}{3} - \nu\right) + \sqrt{3}\left(\frac{G}{\cos\nu} - \frac{\rho_{ao}}{m_n}\right)$$

where

$$\nu = \frac{2G}{z_n}\tan\nu - H$$

$$G = \frac{\rho_{ao}}{m_n} - \frac{h_{ao}}{m_n} + x$$

$$H = \frac{2}{z_n}\left(\frac{\pi}{2} - \frac{E}{m_n}\right) - \frac{\pi}{3}$$

$$E = \frac{\pi}{4} m_n - h_{ao}\tan\alpha_n + \frac{S_{pr}}{\cos\alpha_n} - (1 - \sin\alpha_n)\frac{\rho_{ao}}{\cos\alpha_n}$$

E, h_{ao}, α_n, S_{pr} and ρ_{ao} are shown in Fig. 5.3.2

$$\frac{\rho_F}{m_n} = \frac{\rho_{ao}}{m_n} + \frac{2G^2}{\cos\nu\,(z_n\cos^2\nu - 2G)}$$

$$d_{en} = \frac{2z}{|z|}\left\{\left[\sqrt{\left(\frac{d_{an}}{2}\right)^2 - \left(\frac{d_{bn}}{2}\right)^2} - \frac{\pi d\cos\beta\cos\alpha_n}{|z|}(\varepsilon_{an} - 1)\right]^2 + \left(\frac{d_{bn}}{2}\right)^2\right\}^{1/2}$$

where

$$d_{an} = d_n + d_a - d$$

$$d_n = \frac{d}{\cos^2\beta_b}$$

$$d_{bn} = d_n\cos\alpha_n$$

$$\varepsilon_{an} = \frac{\varepsilon_a}{\cos^2\beta_b}$$

$$\gamma_e = \frac{\dfrac{\pi}{2} + 2x\tan\alpha_n}{z_n} + \text{inv.}\,\alpha_n - \text{inv.}\,\alpha_{en}$$

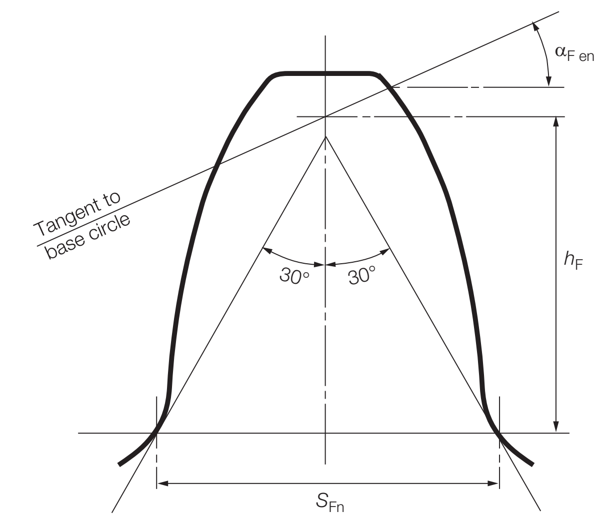
where

$$\alpha_{en} = \arccos\frac{d_{bn}}{d_{en}}$$

$$\frac{h_F}{m_n} = \frac{1}{2}\left[(\cos\gamma_e - \sin\gamma_e\tan\alpha_{F\ en})\frac{d_{en}}{m_n} - z_n\cos\left(\frac{\pi}{3} - \nu\right) - \frac{G}{\cos\nu} + \frac{\rho_{ao}}{m_n}\right]$$

where

$$\alpha_{F\ en} = \alpha_{en} - \gamma_e.$$



NOTE
For helical gears the normal section is taken with the virtual number of teeth

Fig. 5.3.1 Normal tooth section

3.5.3 For internal tooth forms the form factor is calculated, as an approximation, for a substitute gear rack with the form of the basic rack in the normal section, but having the same tooth depth as the internal gear:

$$\frac{S_{Fn2}}{m_n} = 2\left[\frac{\pi}{4} + \tan\alpha\left(\frac{h_{ao2} - \rho_{ao2}}{m_n}\right) + \left(\frac{\rho_{ao2} - S_{pr}}{m_n \cos\alpha_n}\right) - \frac{\rho_{ao2}}{m_n}\cos\frac{\pi}{6}\right], \text{ and}$$

$$\frac{h_{F2}}{m_n} = \frac{d_{en2} - d_{fn2}}{2m_n} - \left[\frac{\pi}{4} + \left(\frac{h_{ao2}}{m_n} - \frac{d_{en2} - d_{fn2}}{2m_n}\right)\tan\alpha_n\right]\tan\alpha_n - \frac{\rho_{ao2}}{m_n}\left(1 - \sin\frac{\pi}{6}\right)$$

where

$\alpha_{F\,en}$ is taken as being equal to α_n

$$\rho_{F2} = \frac{\rho_{ao2}}{2}$$

d_{en2} is calculated as d_{en} for external gears, and

$d_{fn} = d - d_f - d_n$.

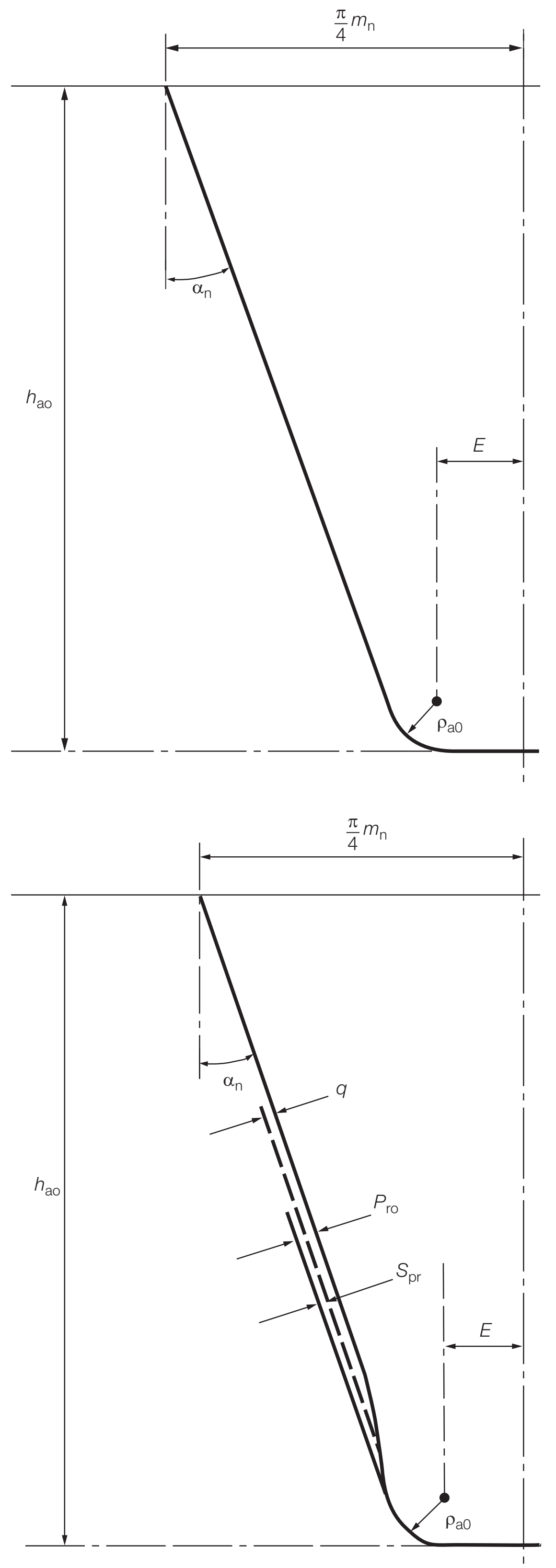
3.5.4 Stress concentration factor, Y_s

$$Y_s = (1{,}2 + 0{,}13L)\, q_s^{\left(\frac{1}{1{,}21 + 2{,}3/L}\right)}$$

where

$$L = \frac{S_{Fn}}{h_F}$$

$$q_s = \frac{S_{Fn}}{2\rho_F}$$



NOTES
1. Dimensions shown on rack profile of tooth
2. $S_{pr} = P_{ro} - q$

Fig. 5.3.2 External tooth forms

when $q_s < 1$ the value of Y_s is to be specially considered. The formula for Y_s is applicable to external gears with $\alpha_n = 20°$ but may be used as an approximation for other pressure angles and internal gears.

3.5.5 Helix angle factor Y_β

$$Y_\beta = 1 - \left(\varepsilon_\beta \frac{\beta}{120}\right), \text{ if } \varepsilon_\beta > 1 \text{ let } \varepsilon_\beta = 1$$

but $Y_b \geq 1 - 0{,}25\varepsilon_b \geq 0{,}75$.

3.5.6 Relative notch sensitivity factor, $Y_{\delta \text{ rel T}}$

$Y_{\delta \text{ rel T}} = 1 + 0{,}036\ (q_s - 2{,}5) \left(1 - \dfrac{\sigma_y}{1200}\right)$ for through-hardened steels

$Y_{\delta \text{ rel T}} = 1 + 0{,}008\ (q_s - 2{,}5)$ for carburised and induction-hardened steels, and

$Y_{\delta \text{ rel T}} = 1 + 0{,}04\ (q_s - 2{,}5)$ for nitrided steels.

3.5.7 Relative surface finish factor, $Y_{\text{R rel T}}$

$Y_{\text{R rel T}} = 1{,}674 - 0{,}529\ (6R_a + 1)^{0{,}1}$ for through-hardened, carburised and induction-hardened steels, and

$Y_{\text{R rel T}} = 4{,}299 - 3{,}259\ (6R_a + 1)^{0{,}005}$ for nitrided steels.

3.5.8 Size factor, Y_x

Y_x = 1,00, when $m_n \leq 5$
Y_x = $1{,}03 - 0{,}006m_n$ for through-hardened steels
Y_x = 0,85, when $m_n \geq 30$
Y_x = $1{,}05 - 0{,}01m_n$ for surface-hardened steels
Y_x = 0,80, when $m_n \geq 25$.

3.5.9 Design factor, Y_D

Y_D = 0,83 for gears treated with a controlled shot peening process
Y_D = 1,5 for idler gears
Y_D = 1,25 for shrunk on gears, or

$$Y_D = 1 + \frac{0{,}2d_s^2\ d\ P_r\ b}{F_t\ \sigma_{\text{F lim}}\ (d_f^2 - d_s^2)}, \text{ otherwise}$$

Y_D = 1,00.

3.6 Factors of safety

3.6.1 Factors of safety are shown in Table 5.3.4.

3.7 Design of enclosed gear shafting

3.7.1 This sub-Section is applicable to shafting enclosed within the gearcase. Final gear wheel shafts and thrust shafts are to be in accordance with Ch 6,3.3 and Ch 6,3.4 respectively.

3.7.2 The diameter of the enclosed gear shafting adjacent to the pinion or wheel is to be not less than the greater of d_b or d_t, where:

$$d_b = 365 \left(\frac{P\,L}{R\,d_w\,S_b}\right)^{1/3} \left(1 + \left(\frac{\tan\alpha_n}{\cos\beta} + \frac{\tan\beta\ d_w}{L}\right)^2\right)^{1/6}$$

$$d_t = 365 \left(\frac{P}{R\,S_s}\right)^{1/3}$$

where
S_b = $45 + 0{,}24\ (\sigma_u - 400)$ and
S_s = $42 + 0{,}09\ (\sigma_u - 400)$
L = span between shaft bearing centres, in mm
α_n = normal pressure angle at the gear reference diameter, in degrees
β = helix angle at the gear reference diameter, in degrees
d_w = pitch circle diameter of the gear teeth, in mm
σ_u = specified minimum tensile strength of the shaft material, in N/mm^2.

NOTE
P in kW and R in rpm are as defined in Ch 1,3.3.
Numerical value used for σ_u is not to exceed 800 N/mm^2 for gear and thrust shafts.

3.7.3 For the purposes of the above it is assumed that the pinion or wheel is mounted symmetrically spaced between bearings.

3.7.4 Outside a length equal to the required diameter at the pinion or wheel, the diameter may be reduced, if applicable, to that required for d_t.

3.7.5 For bevel gear shafts, where a bearing is located adjacent to the gear section, the diameter of the shaft is be not less than d_t. Where a bearing is not located adjacent to the gear the diameter of the shaft will be specially considered.

■ *Section 4* **Construction**

4.1 Gear wheels and pinions

4.1.1 Where castings are used for wheel centres, any radial slots in the periphery are to be fitted with permanent chocks before shrinking-on the rim.

4.1.2 Where bolts are used to secure side plates to rim and hub, the bolts are to be a tight fit in the holes and the nuts are to be suitably locked by means other than welding.

4.1.3 Where welding is employed in the construction of wheels, the welding procedure is to be approved by the Surveyors before work is commenced. For this purpose, welding procedure approval tests are to be carried out with satisfactory results. Such tests are to be representative of the joint configuration and materials. Wheels are to be stress relieved after welding. All welds are to have a satisfactory surface finish and contour. Magnetic particle or liquid penetrant examination of all important welded joints is to be carried out to the satisfaction of the Surveyors.

4.1.4 In general, arrangements are to be made so that the interior structure of the wheel may be examined. Alternative proposals will be specially considered.

4.2 Accuracy of gear cutting and alignment

4.2.1 The machining accuracy (Q grade) of pinions and wheels is to be demonstrated to the satisfaction of the Surveyors. For this purpose, records of measurements should be available for review by Surveyors on request.

4.2.2 Where allowance has been given for end relief or helix correction, the normal shop meshing tests are to be supplemented by tooth alignment traces or other approved means to demonstrate the effectiveness of such modifications.

4.3 Gearcases

4.3.1 Gearcases and their supports are to be designed sufficiently stiff such that misalignment at the mesh due to movements of the external foundations and the thermal effects under all conditions of service do not disturb the overall tooth contact.

4.3.2 For gearcases fabricated by fusion welding the carbon content of steels should generally not exceed 0,23 per cent. Steels with higher carbon content may be approved subject to satisfactory results from weld procedure tests.

4.3.3 Gearcases are to be stress relief heat treated on completion of all welding.

4.3.4 Inspection openings are to be provided at the peripheries of gearcases to enable the teeth of pinions and wheels to be readily examined. Where the construction of gearcases is such that sections of the structure cannot readily be moved for inspection purposes, access openings of adequate size are also to be provided at the ends of the gearcases to permit examination of the structure of the wheels. Their attachment to the shafts is to be capable of being examined by removal of bearing caps or by equivalent means.

■ *Section 5* Tests

5.1 Balance of gear pinions and wheels

5.1.1 All rotating elements, (e.g. pinion and wheel shaft assemblies and coupling parts), are to be appropriately balanced.

5.1.2 The permissible residual unbalance, U, is defined as follows:

$$U = \frac{60m}{N} \times 10^3 \text{ g mm for } N \leq 3000$$

$$U = \frac{24m}{N} \times 10^3 \text{ g mm for } N > 3000$$

where

m = mass of rotating element, kg

N = maximum service rev/min of the rotating element.

5.1.3 Where the size or geometry of a rotating element precludes measurement of the residual unbalance, a full speed running test of the assembled gear unit at the manufacturer's works will normally be required to demonstrate satisfactory operation.

5.2 Meshing tests

5.2.1 Initially, meshing gears are to be carefully matched on the basis of the accuracy measurements taken. The alignment is to be demonstrated in the workshop by meshing in the gearbox without oil clearance in the bearings. Meshing is to be carried out with the gears locating in their light load positions and a load sufficient to overcome pinion weight and axial movement is to be imposed.

5.2.2 The gears are to be suitably coated to demonstrate the contact marking. The marking is to reflect the accuracy grade specified and end relief of helix correction, where these have been applied.

5.2.3 For gears without helix correction, the marking is to be not less than shown in Table 5.5.1.

Table 5.5.1 No load tooth contact marking

ISO accuracy grade	Contact marking area
Q ≤ 5	40% h_w for 50% b and 20% h_w for a further 40% b
Q ≥ 6	40% h_w for 35% b and 20% h_w for a further 35% b

NOTES
1. Where b is face width and h_w is working tooth depth.
2. For spur gears the values of h_w should be increased by a further 10%.

5.2.4 For gears with end relief of helix correction, the marking is to correspond to the designed no load contact pattern.

5.2.5 A permanent record is to be made of the meshing contact for the purpose of checking the alignment when installed on board.

5.2.6 The full load tooth contact marking is to be not less than shown in Table 5.5.2.

Table 5.5.2 Full load tooth contact marking

ISO accuracy grade	Contact marking area
Q ≤ 5	70% h_w for 60% b and 50% h_w for a further 30% b
Q ≥ 6	60% h_w for 45% b and 40% h_w for a further 35% b

NOTES
1. Where b is face width and h_w is working tooth depth.
2. For spur gears the values of h_w should be increased by a further 10%.

5.3 Backlash

5.3.1 The normal backlash between any pair of gears should not be less than:

$$\frac{a\alpha_n}{90\,000} + 0{,}1 \text{ mm}$$

5.3.2 The normal backlash is not to exceed three times the value calculated in 5.3.1.

5.4 Alignment

5.4.1 Reduction gears with sleeve bearings, for main and auxiliary purposes, are to be provided with means for checking the internal alignment of the various elements in the gearcases.

5.4.2 In the case of separately mounted reduction gearing for main propulsion, means are to be provided by the gear manufacturer to enable the Surveyors to verify that no distortion of the gearcase has taken place, when chocked and secured to its seating on board ship.

5.4.3 Further requirements are given in Ch 8,5.

■ *Cross-reference*

For lubricating oil systems, *see* Chapter 14.

■ *Scope*

The requirements of this Chapter relate, in particular, to formulae for determining the diameters of shafting for main propulsion installations, but requirements for couplings, coupling bolts, keys, keyways, sternbushes and other associated components are also included. The diameters may require to be modified as a result of alignment considerations and vibration characteristics, *see* Chapter 8 or the inclusion of stress raisers other than those contained in this Chapter.

Alternative calculation methods for determining the diameters of shafting for main propulsion and their permissible torsional stresses will be considered by LR. Any alternative calculation method is to include all relevant loads on the complete dynamic shafting system under all permissible operating conditions. Consideration is to be given to the dimensions and arrangements of all shaft connections. Moreover, an alternative calculation method is to take into account design criteria for continuous and transient operating loads (dimensioning for fatigue strength) and for peak operating loads (dimensioning for yield strength). The fatigue strength analysis may be carried out separately for different load assumptions, for example as given below.

Shafts complying with the applicable Rules in Chapter 6 and Chapter 8 satisfy the following:

(a) Low cycle fatigue criterion (typically $<10^4$), i.e. the primary cycles represented by zero to full load and back to zero, including reversing torque if applicable. This is addressed by the formulas in Ch 6,3.1, 3.5 and 3.6.

(b) High cycle fatigue criterion (typically $>>10^7$), i.e. torsional vibration stresses permitted for continuous operation as well as reverse bending stresses and the accumulated fatigue due to torsional vibration when passing through a barred speed range or any other transient condition with associated stresses beyond those permitted for continuous operation. This is addressed by the formulas in Ch 8,2.5. The influence of reverse bending stresses is addressed by the safety margins inherent in the formulas from Ch 6,3.1, 3.5 and 3.6.

■ *Section 1*
Plans and particulars

1.1 Shafting plans

1.1.1 The following plans, together with the necessary particulars of the machinery, including the maximum power and revolutions per minute, are to be submitted for consideration before the work is commenced:

- Final gear shaft.
- Thrust shaft.
- Intermediate shafting.
- Tube shaft, where applicable.
- Screwshaft.
- Screwshaft oil gland.
- Sternbush.

1.1.2 The specified minimum tensile strength of each shaft is to be stated.

1.1.3 In addition, a shafting arrangement plan indicating the relative positions of the main engines, flywheel, flexible coupling, gearing, thrust block, line shafting and bearings, sterntube, 'A' bracket and propeller, as applicable, is to be submitted for information.

■ *Section 2*
Materials

2.1 Materials for shafts

2.1.1 The specified minimum tensile strength of forgings for shafts is to be selected within the following general limits:

(a) Carbon and carbon-manganese steel
400 to 760 N/mm^2 (41 to 77,5 kgf/mm^2). *See also* 3.5.1.

(b) Alloy steel
not exceeding 800 N/mm^2 (82 kgf/mm^2).

2.1.2 Where it is proposed to use alloy steel, details of the chemical composition, heat treatment and mechanical properties are to be submitted for approval.

2.1.3 Where shafts may experience vibratory stresses close to the permissible stresses for transient operation, the materials are to have a specified minimum tensile strength of 500 N/mm^2 (51 kgf/mm^2).

2.1.4 Where materials with greater specified or actual tensile strengths than the limitations given above are used, reduced shaft dimensions or higher permissible vibration stresses are not acceptable when derived from the formulae used in 3.1, 3.5, 3.6 and Ch 8,2.5.

2.2 Ultrasonic tests

2.2.1 Ultrasonic tests are required on shaft forgings where the diameter is 250 mm or greater.

Section 3 Design

3.1 Intermediate shafts

3.1.1 The diameter, d, of the intermediate shaft is to be not less than determined by the following formula:

$$d = Fk \sqrt[3]{\frac{P}{R}\left(\frac{560}{\sigma_u + 160}\right)} \text{ mm}$$

$$\left(d = Fk \sqrt[3]{\frac{H}{R}\left(\frac{57}{\sigma_u + 16}\right)} \text{ mm}\right)$$

where

k = 1,0 for shafts with integral coupling flanges complying with 3.7 or with shrink fit couplings, *see* 3.1.4
= 1,10 for shafts with keyways in tapered or cylindrical connections, where the fillet radii in the transverse section of the bottom of the keyway are to be not less than 0,0125d
= 1,10 for shafts with transverse or radial holes where the diameter of the hole (d_h) is not greater than 0,3d
= 1,20 for shafts with longitudinal slots, *see* 3.1.6

F = 95(86) for turbine installations, electric propulsion installations and oil engine installations with slip type couplings
= 100 (90,5) for other oil engine installations P (H) and R are defined in Ch 1,3.3 (losses in gearboxes and bearings are to be disregarded)

σ_u = specified minimum tensile strength of the shaft material, in N/mm^2 (kgf/mm^2), *see* 2.1.3

After a length of 0,2d from the end of a keyway, transverse hole or radial hole and 0,3d from the end of a longitudinal slot, the diameter of the shaft may be gradually reduced to that determined with k = 1,0.

3.1.2 For shafts with design features other than stated in 3.1.1, the value of k will be specially considered.

3.1.3 The Rule diameter of the intermediate shaft for oil engines, turbines and electric propelling motors may be reduced by 3,5 per cent for units classed exclusively for smooth water service, and by 1,75 per cent for units classed exclusively for service on the Great Lakes.

3.1.4 For shrink fit couplings, k refers to the plain shaft section only. Where shafts may experience vibratory stresses close to the permissible stresses for continuous operation, an increase in diameter to the shrink fit diameter is to be provided, e.g., a diameter increase of 1 to 2 per cent and a blending radius as described in 3.8.

3.1.5 Keyways are in general not to be used in installations with a barred speed range.

3.1.6 The application of k = 1,20 is limited to shafts with longitudinal slots having a length of not more than 0,8d and a width of not more than 0,1d and a diameter of central hole d_i of not more than 0,8d, *see* 3.7. The end rounding of the slot is not to be less than half the width. An edge rounding should preferably be avoided as this increases the stress concentration slightly. The values of c_K, *see* Table 8.2.1 in Pt 5, Ch 8, are valid for 1, 2 and 3 slots, i.e. with slots at 360, 180 and 120 degrees apart respectively.

3.2 Gear quill shafts

3.2.1 The diameter of the quill shaft is to be not less than given by the following formula:

$$\text{Diameter of quill shaft} = 101 \sqrt[3]{\frac{P\,400}{R\,\sigma_u}} \text{ mm}$$

$$\left(91 \sqrt[3]{\frac{H\,41}{R\,\sigma_u}} \text{ mm}\right)$$

where

P (H) and R are as defined in Ch 1,3.3

σ_u = specified minimum tensile strength of the material, in N/mm^2 (kgf/mm^2) but is not to exceed 1100 N/mm^2 (112 kgf/mm^2).

3.3 Final gear wheel shafts

3.3.1 Where there is only one pinion geared into the final wheel, or where there are two pinions which are set to subtend an angle at the centre of the shaft of less than 120 degrees, the diameter of the shaft at the final wheel and the adjacent journals is to be not less than 1,15 times that required for the intermediate shaft.

3.3.2 Where there are two pinions geared into the final wheel opposite, or nearly opposite, to each other, the diameter of the shaft at the final wheel and the adjacent journals is to be not less than 1,1 times that required for the intermediate shaft.

3.3.3 In both 3.3.1 and 3.3.2, abaft the journals, the shaft may be gradually tapered down to the diameter required for an intermediate shaft determined according to 3.1, where σ_u is to be taken as the specified minimum tensile strength of the final wheel shaft material, in N/mm^2 (kgf/mm^2).

3.4 Thrust shafts

3.4.1 The diameter at the collars of the thrust shaft transmitting torque, or in way of the axial bearing where a roller bearing is used as a thrust bearing, is to be not less than that required for the intermediate shaft in accordance with 3.1 with a k value of 1,10. Outside a length equal to the thrust shaft diameter from the collars, the diameter may be tapered down to that required for the intermediate shaft with a k value of 1,0. For the purpose of the foregoing calculations, σ_u is to be taken as the minimum tensile strength of the thrust shaft material, in N/mm^2 (kgf/mm^2).

3.5 Screwshafts and tube shafts

3.5.1 The diameter, d_p of the screwshaft immediately forward of the forward face of the propeller boss or, if applicable, the forward face of the screwshaft flange, is to be not less than determined by the following formula:

$$d_p = 100k \sqrt[3]{\frac{P}{R}\left(\frac{560}{\sigma_u + 160}\right)} \text{ mm}$$

$$\left(d_p = 90{,}5k \sqrt[3]{\frac{P}{R}\left(\frac{57}{\sigma_u + 16}\right)} \quad \text{mm}\right)$$

where

k = 1,22 for a shaft carrying a keyless propeller fitted on a taper, or where the propeller is attached to an integral flange, and where the shaft is fitted with a continuous liner or is oil

P (H) and R are defined in Ch 1,3.3, (losses in gearboxes and bearings are to be disregarded)

σ_u = specified minimum tensile strength of the shaft material, in N/mm^2 (kgf/mm^2) but is not to be taken as greater than 600 N/mm^2 (61 kgf/mm^2). *See* 2.1.3.

3.5.2 The diameter, d_p of the screwshaft determined in accordance with the formula in 3.5.1 is to extend over a length not less than that to the forward edge of the bearing immediately forward of the propeller or 2,5d_p, whichever is the greater.

3.5.3 The diameter of the portion of the screwshaft and tube shaft, forward of the length required by 3.5.2 to the forward end of the forward stern tube seal, is to be determined in accordance with the formula in 3.5.1 with a k value of 1,15. The change of diameter from that determined with k = 1,22 or 1,26 to that determined with k = 1,15 should be gradual, *see* 3.7.

3.5.4 Screwshafts which run in sterntubes and tube shafts may have the diameter forward of the forward stern tube seal gradually reduced to the diameter of the intermediate shaft. Abrupt changes in shaft section at the screwshaft/tube shaft to intermediate shaft couplings are to be avoided, *see* 3.7.

3.5.5 Unprotected screwshafts and tube shafts of corrosion-resistant material will be specially considered.

3.5.6 For shafts of non-corrosion-resistant materials which are exposed to sea-water, the diameter of the shaft is to be determined in accordance with the formula in 3.5.1 with a k value of 1,26 and σ_u taken as 400 N/mm^2 (41 kgf/mm^2).

3.6 Hollow shafts

3.6.1 Where the thrust, intermediate and tube shafts and screwshafts have central holes, the outside diameters of the shafts are to be not less than given by the following formula:

$$d_o = d \sqrt[3]{\frac{1}{\left[1 - \left(\frac{d_i}{d_o}\right)^4\right]}}$$

where

d_o = outside diameter, in mm

d = Rule size diameter of solid shaft, in mm

d_i = diameter of central hole, in mm

However, where the diameter of the central hole does not exceed 0,4 times the outside diameter, no increase over Rule size need be provided.

3.7 Couplings and transitions of diameters

3.7.1 The minimum thicknesses of the coupling flanges are to be equal to the diameters of the coupling bolts at the face of the couplings as required by 3.8 and, for this purpose, the minimum tensile strength of the bolts is to be taken as equivalent to that of the shafts. For intermediate shafts, thrust shafts and the inboard end of the screwshaft, the thickness of the coupling flange is in no case to be less than 0,20 of the diameter of the intermediate shaft, as required by 3.1.

3.7.2 The fillet radius at the base of the coupling flange is to be not less than 0,08 of the diameter of the shaft at the coupling but, in the case of crankshafts, the fillet radius at the centre coupling flanges may be 0,05 of the diameter of the shaft at the coupling. The fillets are to have a smooth finish and are not to be recessed in way of nut and bolt heads.

3.7.3 Where the propeller is attached by means of a flange, the thickness of the flange is to be not less than 0,25 of the actual diameter of the adjacent part of the screwshaft. The fillet radius at the base of the coupling flange is to be not less than 0,125 of the diameter of the shaft at the coupling.

3.7.4 All couplings which are attached to shafts are to be of approved dimensions.

3.7.5 Where couplings are separate from the shafts, provision is to be made to resist the astern pull.

3.7.6 Where a coupling is shrunk on to the parallel portion of a shaft or is mounted on a slight taper, e.g., by means of the oil pressure injection method, full particulars of the coupling including the interference fit are to be submitted for special consideration.

3.7.7 Transitions of diameters are to be designed with either a smooth taper or a blending radius. In general, a blending radius equal to the change in diameter is recommended.

3.8 Coupling bolts

3.8.1 Close tolerance fitted bolts transmitting shear are to have a diameter at the joining faces of the couplings not less than given by the following formula:

$$\text{Diameter of coupling bolts} = \sqrt{\frac{240}{nD} \frac{10^6}{\sigma_u} \frac{P}{R}} \quad \text{mm}$$

where

n = number of bolts in the coupling

D = pitch circle diameter of bolts, in mm

σ_u = specified minimum tensile strength of bolts, in N/mm^2

P, (H) and R are as defined in Ch 1,3.3.

3.8.2 At the joining faces of couplings, other than within the crankshaft and at the thrust shaft/crankshaft coupling, the Rule diameter of the coupling bolts defined in 3.8.1 may be reduced by 5,2 per cent for units classed exclusively for smooth water service, and 2,6 per cent for units classed exclusively for service on the Great Lakes.

3.8.3 Where dowels or expansion bolts are fitted to transmit torque in shear, they are to comply with the requirements of 3.8.1. The expansion bolts are to be installed, and the bolt holes in the flanges are to be correctly aligned, in accordance with manufacturer's instructions.

3.8.4 The minimum diameter of tap bolts or of bolts in clearance holes at the joining faces of coupling flanges, pre-tensioned to 70 per cent of the bolt material yield strength value, is not to be less than:

$$d_R = 1{,}348\sqrt{\left(\frac{120\ 10^6\,F\,P\,(1+C)}{R\,D} + Q\right)\frac{1}{n\,\sigma_y}}$$

where

d_R is taken as the lesser of:

(a) Mean of effective (pitch) and minor diameters of the threads.

(b) Bolt shank diameter away from threads. (Not for waisted bolts, which will be specially considered.)

P, (H) and R are as defined in Ch 1,3.3.

F = 2,5 where the flange connection is not accessible from within the unit
= 2,0 where the flange connection is accessible from within the unit

C = ratio of vibratory/mean torque values at the rotational speed being considered

D = pitch circle diameter of bolt holes, in mm

Q = external load on bolt in N (+ve tensile load tending to separate flange, –ve)

n = number of tap or clearance bolts

σ_y = bolt material yield stress in N/mm^2.

3.8.5 Consideration will be given to those arrangements where the bolts are pre-tensioned to loads other than 70 per cent of the material yield strength.

3.8.6 Where clamp bolts are fitted, they are to comply with the requirements of 3.8.4 and are to be installed, and the bolt holes in the flanges correctly aligned, in accordance with manufacturer's instructions.

3.9 Bronze or gunmetal liners on shafts

3.9.1 The thickness, t, of liners fitted on screwshafts or on tube shafts, in way of the bushes, is to be not less, when new, than given by the following formula:

$$t = \frac{D + 230}{32} \text{ mm}$$

where

t = thickness of the liner, in mm

D = diameter of the screwshaft or tube shaft under the liner, in mm.

3.9.2 The thickness of a continuous liner between the bushes is to be not less than 0,75t.

3.9.3 Continuous liners should preferably be cast in one piece.

3.9.4 Where liners consist of two or more lengths, these are to be butt welded together. In general, the lead content of the gunmetal of each length forming a butt welded liner is not to exceed 0,5 per cent. The composition of the electrodes or filler rods is to be substantially lead-free.

3.9.5 The circumferential butt welds are to be of multi-run, full penetration type. Provision is to be made for contraction of the weld by arranging for a suitable length of the liner containing the weld, if possible about three times the shaft diameter, to be free of the shaft. To prevent damage to the surface of the shaft during welding, a strip of heat-resisting material covered by a copper strip should be inserted between the shaft and the liner in way of the joint. Other methods for welding this joint may be accepted if approved. The welding is to be carried out by an approved method and to the Surveyor's satisfaction.

3.9.6 Each continuous liner or length of liner is to be tested by hydraulic pressure to 2,0 bar (2,0 kgf/cm^2) after rough machining.

3.9.7 Liners are to be carefully shrunk on, or forced on, to the shafts by hydraulic pressure. Pins are not to be used to secure the liners.

3.9.8 Effective means are to be provided for preventing water from reaching the shaft at the part between the after end of the liner and the propeller boss.

3.10 Keys and keyways

3.10.1 Round ended or sled-runner ended keys are to be used, and the keyways in the propeller boss and cone of the screwshaft are to be provided with a smooth fillet at the bottom of the keyways. The radius of the fillet is to be at least 0,0125 of the diameter of the screwshaft at the top of the cone. The sharp edges at the top of the keyways are to be removed.

3.10.2 Two screwed pins are to be provided for securing the key in the keyway, and the forward pin is to be placed at least one-third of the length of the key from the end. The depth of the tapped holes for the screwed pins is not to exceed the pin diameter, and the edges of the holes are to be slightly bevelled.

3.10.3 The distance between the top of the cone and the forward end of the keyway is to be not less than 0,2 of the diameter of the screwshaft at the top of the cone.

3.10.4 The effective sectional area of the key in shear is to be not less than $\dfrac{d^3}{2{,}6d_1}$ mm^2

where

d = diameter, in mm, required for the intermediate shaft determined in accordance with 3.1, based on material having a specified minimum tensile strength of 400 N/mm^2 (41 kgf/mm^2) and k = 1

d_1 = diameter of shaft at mid-length of the key, in mm.

3.11 Propellers

3.11.1 For keyed and keyless propellers, *see* Chapter 7.

3.12 Sternbushes

3.12.1 The length of the bearing in the sternbush next to and supporting the propeller is to be as follows:

(a) For water lubricated bearings which are lined with lignum vitae, rubber composition or staves of approved plastics material, the length is to be not less than four times the diameter required for the screwshaft under the liner.

(b) For water lubricated bearings lined with two or more circumferentially spaced sectors of an approved plastics material, in which it can be shown that the sectors operate on hydrodynamic principles, the length of the bearing is to be such that the nominal bearing pressure will not exceed 5,5 bar (5,6 kgf/cm^2). The length of the bearing is to be not less than twice its diameter.

(c) For oil lubricated bearings of synthetic material, the flow of lubricant is to be such that overheating, under normal operating conditions, cannot occur. The acceptable nominal bearing pressure will be considered upon application and is to be supported by the results of an agreed test programme. In general, the length of the bearing is not to be less than 2,0 times the Rule diameter of the shaft in way of the bearing.

(d) For bearings which are white-metal lined, oil lubricated and provided with an approved type of oil sealing gland, the length of the bearing is to be approximately twice the diameter required for the screwshaft and is to be such that the nominal bearing pressure will not exceed 8,0 bar (8,1 kgf/cm^2). The length of the bearing is to be not less than 1,5 times its diameter.

(e) For bearings of cast iron and bronze which are oil lubricated and fitted with an approved oil sealing gland, the length of the bearing is, in general, to be not less than four times the diameter required for the screwshaft.

(f) For bearings which are grease lubricated, the length of the bearing is to be not less than four times the diameter required for the screwshaft.

3.12.2 Forced water lubrication is to be provided for all bearings lined with rubber or plastics and for those bearings lined with lignum vitae where the shaft diameter is 380 mm or over. The supply of water may come from a circulating pump or other pressure source. Flow indicators are to be provided for the water service to plastics and rubber bearings. The water grooves in the bearings are to be of ample section and of a shape which will be little affected by weardown, particularly for bearings of the plastics type.

3.12.3 Bearings of synthetic material are to be supplied finished machined to design dimensions within a rigid bush. Means are to be provided to prevent rotation of the lining within the bush during operation.

3.12.4 All sternbushes are to be adequately secured in the sterntube/housings.

3.12.5 The shut-off valve or cock controlling the supply of water is to be fitted directly to the after peak bulkhead, or to the sterntube where the water supply enters the sterntube forward of the bulkhead.

3.12.6 Oil sealing glands fitted in units classed for unrestricted service must be capable of accommodating the effects of differential expansion between hull and line of shafting in sea temperatures ranging from arctic to tropical. This requirement applies particularly to those glands which span the gap and maintain oiltightness between the sterntube and the propeller boss.

3.12.7 Where a tank supplying lubricating oil to the sternbush is fitted, it is to be located above the load waterline and is to be provided with a low level alarm device in the engine room.

3.12.8 Where sternbush bearings are oil lubricated, provision is to be made for cooling the oil by maintaining water in the after peak tank above the level of the sterntube or by other approved means. Means for ascertaining the temperature of the oil in the sterntube are also to be provided.

3.12.9 Where there is compliance with the terms of 3.12.1(c) and (d) to the Surveyor's satisfaction, a screwshaft will be assigned the notation **OG** in the *Supplement to the Register Book* for Periodical Survey purposes, *see* Pt 1, Ch 3.

3.12.10 Screwshafts which are grease lubricated are not eligible for the **OG** notation.

3.12.11 Where an **OIWS** (In-water Survey) notation is to be assigned, *see* Pt 1, Ch 2,2.4.13, means are to be provided for ascertaining the clearance in the sternbush with the vessel afloat.

3.13 Vibration and alignment

3.13.1 For the requirements for torsional, axial and lateral vibration, and for alignment of the shafting, *see* Chapter 8.

Section

■ *Section 1*
Plans and particulars

1.1 Details to be submitted

1.1.1 A plan, in triplicate, of the propeller is to be submitted for approval, together with the following particulars using the symbols shown:

(a) Maximum blade thickness of the expanded cylindrical section considered, *T*, in mm.
(b) Maximum shaft power, *see* Ch 1,3.3, *P*, in kW (*H*, in shp).
(c) Estimated unit speed at design loaded draught in the free running condition at maximum shaft power and corresponding revolutions per minute, *see* (b) and (d).
(d) Revolutions per minute of the propeller at maximum power, *R*.
(e) Propeller diameter, *D*, in metres.
(f) Pitch at 25 per cent radius (for solid propellers only), $P_{0,25}$, in metres.
(g) Pitch at 35 per cent radius (for controllable pitch propellers only), $P_{0,35}$, in metres.
(h) Pitch at 60 per cent radius $P_{0,6}$, in metres.
(j) Pitch at 70 per cent radius $P_{0,7}$, in metres.
(k) Length of blade section of the expanded cylindrical section at 25 per cent radius (for solid propellers only), $L_{0,25}$, in mm.
(l) Length of blade section of the expanded cylindrical section at 35 per cent radius (for controllable pitch propellers only) $L_{0,35}$, in mm.
(m) Length of blade section of the expanded cylindrical section at 60 per cent radius, $L_{0,6}$, in mm.
(n) Rake at blade tip measured at shaft axis (backward rake positive, forward rake negative), *A*, in mm.
(o) Number of blades, *N*.
(p) Developed area ratio, *B*.
(q) Material: type and specified minimum tensile strength.
(r) θ_s, skew angle, in degrees, *see* Fig. 7.1.1.
(s) Connection of propeller to shaft – details of fit, push-up, securing, etc.

1.1.2 For propellers having a skew angle equal to or greater than 50°, in addition to the particulars detailed in 1.1.1, details are to be submitted of:

(a) Full blade section details at each radial station defined for manufacture.
(b) A detailed blade stress computation supported by the following hydrodynamic data for the ahead mean wake condition and when absorbing full power:

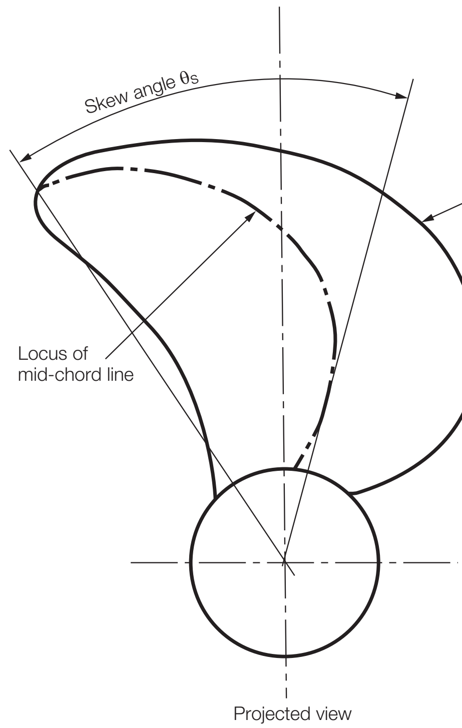


Fig. 7.1.1 Definition of skew angle

(i) Radial distribution of lift and drag coefficients, section inflow velocities and hydrodynamic pitch angles.
(ii) Section pressure distributions calculated by either an advised inviscid or viscous procedure.

1.1.3 For blades of fixed pitch propellers with skew angle of 30º or greater, the stresses in the propeller blade during astern operation are not to exceed 80 per cent of the propeller blade material proof stress. Consideration is to be given to failure conditions and a factor of safety of 1,5 is to be attained using an acceptable fatigue failure criterion. Documentary evidence confirming that these criteria are satisfied is to be submitted.

1.1.4 The maximum skew angle of a propeller blade is defined as the angle, in projected view of the blade, between a line drawn through the blade tip and the shaft centreline and a second line through the shaft centreline which acts as a tangent to the locus of the mid-points of the helical blade sections, *see* Fig. 7.1.1.

1.1.5 Where propellers and similar devices of unusual design are intended for more than one operating regime, such as towing or trawling, then a detailed blade stress calculation for each operating condition, indicating the rotational and unit speed, is to be submitted for consideration.

1.1.6 Where it is proposed to fit the propeller to the screwshaft without the use of a key, plans of the boss, tapered end of screwshaft, propeller nut and, where applicable, the sleeve, are to be submitted.

1.1.7 Where a sleeve is fitted, details of the proposed type of material and mechanical properties are also to be submitted.

1.1.8 In cases where the unit has been the subject of model wake field tests, a copy of the results is to be submitted.

Section 2
Materials

2.1 Castings

2.1.1 Castings for propellers and propeller blades are to comply with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials). The specified minimum tensile strength is to be not less than stated in Table 7.2.1.

2.1.2 Where it is proposed to use materials which are not included in Table 7.2.1, details of the chemical composition, mechanical properties and density are to be submitted for approval.

2.1.3 Spheroidal cast iron load transmitting components of controllable pitch mechanisms, are to be manufactured, tested and certified in accordance with Chapter 7 of the Rules for Materials, and have an elongation of not less than 12 per cent.

Section 3
Design

3.1 Minimum blade thickness

3.1.1 For propellers having a skew angle of 25° or less, as defined in 1.1.4, the minimum blade thickness, T, of the propeller blades at 25 per cent radius for solid propellers, 35 per cent radius for controllable pitch propellers, neglecting any increase due to fillets, and at 60 per cent radius, is to be not less than:

$$T = \frac{KCA}{EFULN} + 100\sqrt{\frac{3150MP}{EFRULN}} \text{ mm}$$

$$\left(T = \frac{KCA}{9{,}81EFULN} + 27{,}4\sqrt{\frac{3150MH}{EFRULN}} \text{ mm}\right)$$

where

L = $L_{0,25}$, $L_{0,35}$, or $L_{0,6}$, as appropriate

$K = \dfrac{GBD^3R^2}{675}$

G = density, in g/cm^3, *see* Table 7.2.1

U = allowable stress, in N/mm^2 (kgf/mm^2) *see* 3.1.2, 3.1.3, 3.1.4, and Table 7.2.1

$E = \dfrac{\text{actual face modulus}}{0{,}09T^2 L}$

For aerofoil sections with and without trailing edge washback, E may be taken as 1,0 and 1,25 respectively

Table 7.2.1 Materials for propellers

Material	SI units: Specified minimum tensile strength N/mm^2	SI units: G Density g/cm^3	SI units: U Allowable stress N/mm^2	Metric units: Specified minimum tensile strength kgf/mm^2	Metric units: G Density g/cm^3	Metric units: U Allowable stress kgf/mm^2
Grey cast iron	250	7,2	17,2	25	7,2	1,75
Spheroidal or nodular graphite cast iron	400	7,3	20,6	41	7,3	2,1
Carbon steels	400	7,9	20,6	41	7,9	2,1
Low alloy steels	440	7,9	20,6	45	7,9	2,1
13% chromium stainless steels	540	7,7	41	55	7,7	4,2
Chromium-nickel austenitic stainless steel	450	7,9	41	46	7,9	4,2
Duplex stainless steels	590	7,8	41	60	7,8	4,2
Grade Cu 1 Manganese bronze (high tensile brass)	440	8,3	39	45	8,3	4,0
Grade Cu 2 Ni-Manganese bronze (high tensile brass)	440	8,3	39	45	8,3	4,0
Grade Cu 3 Ni-Aluminium bronze	590	7,6	56	60	7,6	5,7
Grade Cu 4 Mn-Aluminium bronze	630	7,5	46	64	7,5	4,7

$$C = 1,0$$
$$F = \frac{P_{0,25}}{D} + 0,8$$
$$M = 1,0 + \frac{3,75D}{P_{0,7}} + 2,8\frac{P_{0,25}}{D}$$
for solid propellers at 25 per cent radius

$$C = 1,4$$
$$F = \frac{P_{0,35}}{D} + 1,6$$
$$M = 1,35 + \frac{5D}{P_{0,7}} + 2,6\frac{P_{0,35}}{D}$$
for controllable pitch propellers at 35 per cent radius

$$C = 1,6$$
$$F = \frac{P_{0,6}}{D} + 4,5$$
$$M = 1,35 + \frac{5D}{P_{0,7}} + 1,35\frac{P_{0,6}}{D}$$
for all propellers at 60 per cent radius

3.1.2 The fillet radius between the root of a blade and the boss of a propeller is to be not less than the Rule thickness of the blade or equivalent at this location. Composite radiused fillets or elliptical fillets which provide a greater effective radius to the blade are acceptable and are to be preferred. Where fillet radii of the required size cannot be provided, the value of U is to be multiplied by $\left(\frac{r}{T}\right)^{0,2}$

where

r = proposed fillet radius at the root, in mm
T = Rule thickness of the blade at the root, in mm

Where a propeller has bolted-on blades, consideration is also to be given to the distribution of stress in the palms of the blades. In particular, the fillets of recessed bolt holes and the lands between bolt holes are not to induce stresses which exceed those permitted at the outer end of the fillet radius between the blade and the palm.

3.1.3 For propellers having skew angles of greater than 25°, but less than 50°, the mid-chord thickness, $T_{sk0,6}$, at the 60 per cent radius is to be not less than:

$$T_{sk0,6} = 0,54T_{0,6}\sqrt{1 + 0,1\theta_s} \quad \text{mm}$$

The mid-chord thickness, $T_{sk\ root}$, at 25 or 35 per cent radius, neglecting any increase due to fillets, is to be not less than:

$$T_{sk\ root} = 0,75T_{root}\sqrt[4]{1 + 0,1\theta_s} \quad \text{mm}$$

where

θ_s = proposed skew angle as defined in 1.1.4
$T_{0,6}$ = thickness at 60 per cent radius, calculated by 3.1.1, in mm
T_{root} = thickness at 25 per cent radius or 35 per cent radius, calculated by 3.1.1, in mm

The thicknesses at the remaining radii are to be joined by a fair curve and the sections are to be of suitable aerofoil section.

3.1.4 Results of detailed calculations, where carried out, are to be submitted.

3.1.5 For cases where the composition of the propeller material is not specified in Table 7.2.1, or where propellers of the cast irons and carbon and low alloy steels shown in this Table are provided with an approved method of cathodic protection, special consideration will be given to the value of U.

3.1.6 The value U may be increased by 10 per cent for twin screw and outboard propellers of triple screw units.

3.1.7 Where the design of a propeller has been based on analysis of reliable wake survey data in conjunction with a detailed fatigue analysis and is deemed to permit scantlings less than required by 3.1.1 or 3.1.3, a detailed stress computation for the blades is to be submitted for consideration.

3.2 Keyless propellers

3.2.1 The symbols used in 3.2.2 (oil injection method of fitting) and 3.2.3 to 3.2.7 (dry fitting cast iron sleeve) are defined as follows:

d_1 = diameter of the screwshaft cone at the mid-length of the boss or sleeve, in mm
d_2 = outside diameter of the sleeve at its mid-length, in mm
d_3 = outside diameter of the boss at its mid-length, in mm
d_i = bore diameter of screwshaft, in mm

$$h = \frac{2}{E_2}\left(\frac{1}{k_1^2 - 1}\right)$$
$$k_1 = \frac{d_2}{d_1}$$
$$k_2 = \frac{d_3}{d_2}$$
$$k_3 = \frac{d_3}{d_1}$$
$$l = \frac{d_i}{d_1}$$
$$p_1 = \frac{2M}{A_1\theta_1 V_1}\left(-1 + \sqrt{1 + V_1\left(\frac{F_1^2}{M^2} + 1\right)}\right)$$
$$p_2 = \frac{2M}{A_2\theta_2 V_2}\left(-1 + \sqrt{1 + V_2\left(\frac{F_2^2}{M^2} + 1\right)}\right)$$
$$p_{10} = \frac{2M}{A_1\theta_1 V_1}\left(-1 + \sqrt{1 + V_1\left(\frac{F_{10}^2}{M^2} + 1\right)}\right)$$
$$p_{20} = \frac{2M}{A_2\theta_2 V_2}\left(-1 + \sqrt{1 + V_2\left(\frac{F_{20}^2}{M^2} + 1\right)}\right)$$

A_1 = contact area of fitting at screwshaft, in mm^2
A_2 = contact area of fitting at outside of sleeve, in mm^2

$$B_1 = \frac{1}{E_2}\left(\frac{k_1^2 + 1}{k_1^2 - 1} + \nu_2\right) + \frac{1}{E_1}\left(\frac{1 + l^2}{1 - l^2} - \nu_1\right)$$

$B_2 \;=\; \dfrac{1}{E_3}\left(\dfrac{k_2^2 + 1}{k_2^2 - 1} + \nu_3\right) + \dfrac{1}{E_2}\left(\dfrac{k_1^2 + 1}{k_1^2 - 1} - \nu_2\right)$

$B_3 \;=\; \dfrac{1}{E_3}\left(\dfrac{k_3^2 + 1}{k_3^2 - 1} + \nu_3\right) + \dfrac{1}{E_1}\left(\dfrac{1 + l^2}{1 - l^2} - \nu_1\right)$

C = 0 for turbine installations

= $\dfrac{\text{vibratory torque at the maximum service speed}}{\text{mean torque at the maximum service speed}}$ for oil engine installations

E_1 = modulus of elasticity of screwshaft material, in N/mm^2 (kgf/mm^2)

E_2 = modulus of elasticity of sleeve material, in N/mm^2 (kgf/mm^2)

E_3 = modulus of elasticity of propeller material, in N/mm^2 (kgf/mm^2)

$F_1 \;=\; \dfrac{2Q}{d_1}\,(1 + C)$

$F_2 \;=\; \dfrac{2Q}{d_2}\,(1 + C)$

$F_{10} \;=\; \dfrac{2Q}{d_1}\left(1 + C + \dfrac{I_f}{100}\right)$

$F_{20} \;=\; \dfrac{2Q}{d_2}\left(1 + C + \dfrac{I_f}{100}\right)$

I_f = percentage increase for Ice Class 1D, obtained from Table 2.5.1 in Pt 8, Ch 2,5 of the Rules for Ships

M = propeller thrust, in N (kgf)

Q = mean torque corresponding to P, (H) and R as defined in Ch 1,3.3, in N mm (kgf mm)

T_1 = temperature at time of fitting propeller on shaft, in °C

T_2 = temperature at time of fitting sleeve into boss, in °C

$V_1 \;=\; 0{,}51\left(\dfrac{\mu_1}{\theta_1}\right)^2 - 1$

$V_2 \;=\; 0{,}51\left(\dfrac{\mu_2}{\theta_2}\right)^2 - 1$

$Y \;=\; B_1\,B_2 - h^2\,k_1^2$

α_1 = coefficient of linear expansion of screwshaft material, in mm/mm/°C

α_2 = coefficient of linear expansion of sleeve material, in mm/mm/°C

α_3 = coefficient of linear expansion of propeller material, in mm/mm/°C

θ_1 = taper of the screwshaft cone, but is not to exceed $\dfrac{1}{15}$ on the diameter, i.e. $\theta_1 \leq \dfrac{1}{15}$

θ_2 = taper of the outside of the sleeve

μ_1 = coefficient of friction for fitting of boss assembly on shaft

= 0,13 for oil injection method of fitting

μ_2 = coefficient of friction for fitting sleeve into the boss

ν_1 = Poisson's ratio for screwshaft material

ν_2 = Poisson's ratio for sleeve material

ν_3 = Poisson's ratio for propeller material

Consistent sets of units are to be used in all formulae.

3.2.2 Where it is proposed to fit a keyless propeller by the oil shrink method, the pull-up, δ, on the screwshaft is to be not less than:

$$\delta_T \;=\; \frac{d_1}{\theta_1}\,\left(p_1\,B_3 + (\alpha_3 - \alpha_1)(35 - T_1)\right) \quad \text{mm}$$

or, where Ice Class notation is required, the greater of δ_T or δ_O,

where

$$\delta_O \;=\; \frac{d_1}{\theta_1}\,\left(p_{10}\,B_3 - (\alpha_3 - \alpha_1)\,T_1\right) \quad \text{mm}$$

The yield stress or 0,2 per cent proof stress, σ_o, of the propeller material is to be not less than:

$$\sigma_O \;=\; \frac{1{,}4}{B_3}\left(\frac{\theta_1\,\delta_p}{d_1} + T_1\,(\alpha_3 - \alpha_1)\right)\frac{\sqrt{3k_3^4 + 1}}{k_3^2 - 1} \quad \text{N/mm}^2 \;(\text{kgf/mm}^2)$$

where

δ_p = proposed pull-up at the fitting temperature

The start point load, W, to determine the actual pull-up is to be not less than:

$$W \;=\; A_1\left(0{,}002 + \frac{\theta_1}{20}\right)\left(p_1 + \frac{18}{B_3}\,(\alpha_3 - \alpha_1)\right) \quad \text{N (kgf)}$$

3.2.3 Where a cast iron sleeve is first fitted to the bore of the propeller boss by an interference fit, the push-up load of the sleeve into the boss, W_2, is to be not less than:

$$W_{2T} \;=\; \frac{A_2}{B_2}\left(\mu_2 + \frac{\theta_2}{2}\right)\left(B_2\,p_2 - hp_1 + (\alpha_3 - \alpha_2)(35 - T_2)\right) \quad \text{N (kgf)}$$

or, where Ice Class notation is required, the greater of W_{2T} or W_{20},

where

$$W_{20} \;=\; \frac{A_2}{B_2}\left(\mu_2 + \frac{\theta_2}{2}\right)\left(B_2\,p_{20} - hp_{10} - (\alpha_3 - \alpha_2)\,T_2\right) \quad \text{N (kgf)}$$

The pull-up of the sleeve in the boss at the fitting temperature is to be in accordance with the following formula:

$$\delta_2 \;=\; \frac{W_2\,B_2\,d_2}{A_2\left(\mu_2 + \dfrac{\theta_2}{2}\right)\theta_2} \quad \text{mm}$$

The push-up load, W_1, of the combined boss and sleeve on a steel screwshaft is to be not less than:

$$W_{1T} \;=\; A_1\left(\mu_1 + \frac{\theta_1}{2}\right)\left(p_1 + \frac{hk_1^2}{Y}\,(\alpha_3 - \alpha_2)(35 - T_1)\right) \quad \text{N (kgf)}$$

or where Ice Class notation is required, the greater of W_{1T} or W_{10},

where

$$W_{10} \;=\; A_1\left(\mu_1 + \frac{\theta_1}{2}\right)\left(p_{10} - \frac{hk_1^2}{Y}\,(\alpha_3 - \alpha_2)T_1\right) \quad \text{N (kgf)}$$

The push-up distance of the combined boss and sleeve on a steel screwshaft is to be in accordance with the following formula:

$$\delta_1 \;=\; \frac{W_1\,d_1\,Y}{A_1\,B_2\,\theta_1\left(\mu_1 + \dfrac{\theta_1}{2}\right)} \quad \text{mm}$$

3.2.4 Where a cast iron sleeve is fitted into the boss by means of Araldite, the conditions are to satisfy those of 3.2.3, except that the value of W_2 is to be taken as equivalent to:

$$W_2 = A_2 \left(0{,}25 + \frac{\theta_2}{2}\right)\left(p_A + \frac{(\alpha_3 - \alpha_2)(18 - T_2)}{B_2}\right) \text{ N (kgf)}$$

where

p_A = 3,5 N/mm^2

(p_A = 0,35 kgf/mm$_2$)

3.2.5 For the triple element keyless propeller, the yield stress or 0,2 per cent proof stress of the propeller material, σ_o, is to be not less than:

$$\sigma_o = 1{,}4 p_3 \sqrt{\frac{3k_2^4 + 1}{k_2^2 - 1}} \text{ N/mm}^2 \text{ (kgf/mm}^2\text{)}$$

where

$$p_3 = \frac{W_1\, h}{A_1\, B_2 \left(\mu_1 + \frac{\theta_1}{2}\right)} + \frac{W_2}{A_2 \left(\mu_2 + \frac{\theta_2}{2}\right)} + \frac{\alpha_3 - \alpha_2}{B_2}\left(T_2 + \frac{h^2\, k_1^2}{Y}\, T_1\right)$$

3.2.6 Where the sleeve is manufactured of material having an elongation in excess of five per cent, the yield point or 0,2 per cent proof stress of the sleeve material, σ_o, is to be not less than:

$$\sigma_o = \frac{1{,}6}{k_1^2 - 1} \sqrt{3k_1^4 (p_3 - p_5)^2 + (p_3\, k_1^2 - p_5)^2} \text{ N/mm}^2 \text{ (kgf/mm}^2\text{)}$$

or

$$\sigma_o = \frac{1{,}6}{k_1^2 - 1} \sqrt{3k_1^4 (p_4 - p_6)^2 + (p_4\, k_1^2 - p_6)^2} \text{ N/mm}^2 \text{ (kgf/mm}^2\text{)}$$

where

$$p_4 = p_3 - \frac{35B_1}{Y} (\alpha_3 - \alpha_2)$$

$$p_5 = \frac{W_1}{A_1 \left(\mu_1 + \frac{\theta_1}{2}\right)} + \frac{h\, k_1^2}{Y} (\alpha_3 - \alpha_2)\, T_1$$

$$p_6 = p_5 - \frac{35h\, k_1^2}{Y} (\alpha_3 - \alpha_2)$$

3.2.7 Where the sleeve is manufactured of material having an elongation of not more than five per cent, the minimum specified ultimate tensile strength σ_u, based on the ruling section, is to be not less than:

$$\sigma_u = \frac{2{,}4}{k_1^2 - 1} \left(p_5 \left(\frac{5k_1^2 + 3}{4}\right) - 2p_3\, k_1^2\right) \text{ N/mm}^2 \text{ (kgf/mm}^2\text{)}$$

or

$$\sigma_u = \frac{2{,}4}{k_1^2 - 1} \left(p_6 \left(\frac{5k_1^2 + 3}{4}\right) - 2p_4\, k_1^2\right) \text{ N/mm}^2 \text{ (kgf/mm}^2\text{)}$$

3.2.8 Where it is proposed to use a sleeve manufactured from a material other than cast iron, full details are to be submitted for consideration.

■ *Section 4* Fitting of propellers

4.1 Propeller boss

4.1.1 The propeller boss is to be a good fit on the screwshaft cone. The forward edge of the bore of the propeller boss is to be rounded to about a 6 mm radius. In the case of keyed propellers, the length of the forward fitting surface is to be about one diameter and where the fitting is by means of a hydraulic nut, the requirements of 4.2 and 4.3, where appropriate, are applicable.

4.2 Shop tests of keyless propellers

4.2.1 The bedding of the propeller, or the sleeve where applicable, with the shaft is to be demonstrated in the shop to the satisfaction of the Surveyors. Sufficient time is to be allowed for the temperature of the components to equalise before bedding. Alternative means for demonstrating the bedding of the propeller will be considered.

4.2.2 Means are to be provided to indicate the relative axial position of the propeller boss on the shaft taper.

4.3 Final fitting of keyless propellers

4.3.1 After verifying that the propeller and shaft are at the same temperature and the mating surfaces are clean and free from oil or grease, the propeller is to be fitted on the shaft to the satisfaction of the Surveyors. The propeller nut is to be securely locked to the shaft.

4.3.2 Permanent reference marks are to be made on the propeller boss, nut and shaft to indicate angular and axial positioning of the propeller. Care is to be taken in marking the inboard end of the shaft taper to minimise stress raising effects.

4.3.3 The outside of the propeller boss is to be hard stamped with the following details:

(a) For the oil injection method of fitting, the start point load and the axial pull-up at 0°C and 35°C.

(b) For the dry fitting method, the push-up load at 0°C and 35°C.

4.3.4 A copy of the fitting curve relative to temperature and means for determining any subsequent movement are to be placed on board.

Section

■ *Scope*

The requirements of this Chapter are applicable to the following systems:

(a) Main propulsion systems formed by oil engines, turbines or electric motors, directly driven or geared to the shafting.

(b) Machinery driven at constant speed by oil engines, developing 110 kW and over, for essential auxiliary services including generator sets, which are the source of power for main electric propulsion motors.

Unless otherwise advised, it is the responsibility of the Builder as main contractor to ensure, in co-operation with the Enginebuilders, that the information required by this Chapter is prepared and submitted.

■ *Section 1* General

1.1 Basic requirements

1.1.1 The systems are to be free from excessive torsional, axial, lateral and linear vibration, and are to be aligned in accordance with accepted tolerances, taking into account the requirements of 5.5.

1.1.2 System designs are to take account of the potential effects of engine and component malfunction and variability in characteristic values such as stiffness and damping of flexible couplings and dampers or engine misfire conditions.

1.1.3 Where torques, stresses or amplitudes are found to exceed the limits for continuous operation, restrictions in speed and/or power will be imposed.

1.1.4 Where significant changes are subsequently made to a dynamic system which has been approved, (e.g., by changing the original design parameters of the prime movers and/or propulsion shafting system or by fitting a propeller or flexible coupling of different design from the previous one), revised calculations may require to be submitted for consideration. Details of all such changes are to be submitted.

1.2 Resilient mountings

1.2.1 For resilient mountings, *see* Ch 1,4.3.

1.3 Flexible couplings

1.3.1 Where the shafting system incorporates flexible couplings, the effects of such couplings on the various modes of vibration are to be considered, *see* Sections 2, 3 and 4.

■ *Section 2* Torsional vibration

2.1 General

2.1.1 In addition to the shafting complying with the requirements of Chapters 1 to 7 and 20 (where applicable), approval is also dependent on the torsional vibration characteristics of the complete shafting system(s) being found satisfactory.

2.1.2 Further to the Scope of this Chapter, the requirements of this Section are not applicable to units that are not:

(a) required to comply with the *International Convention for the Safety at Sea,1974*, as amended, (SOLAS); or

(b) where a main engine does not have a power output exceeding 500 kW.

2.2 Particulars to be submitted

2.2.1 Torsional vibration calculations, showing the mass elastic values, associated natural frequencies and an analysis of the vibratory torques and stresses for the full dynamic system.

2.2.2 Particulars of the division of power and utilisation, throughout the speed range, for turbines, multi-engine or other combined power installations, and those with power take-off systems. For multi-engined installations, special considerations associated with the possible variations in the mode of operation and phasing of engines.

2.2.3 Enginebuilder's harmonic torque data used in the torsional vibration calculations, *see* 2.3.3.

2.2.4 Details of operating conditions encountered in service for prolonged periods, e.g., idling speed, range of trawling revolutions per minute, combinator characteristics for installations equipped with controllable pitch propellers.

2.2.5 Details, obtained from the manufacturers, of the principal characteristics of machinery components such as dampers and couplings, confirming their capability to withstand the effects of vibratory loading, including, where appropriate, heat dissipation. Evidence that the data which is used to represent the characteristics of components, which has been quoted from other sources, is supported by a programme of physical measurement and control.

2.2.6 Where installations include electric motors, generators or non-integral pumps, drawings showing the principal dimensions of the shaft, together with manufacturer's estimates of mass moment of inertia for the rotating parts.

2.2.7 Details of vibration or performance monitoring proposals where required.

2.3 Scope of calculations

2.3.1 Calculations are to be carried out, by recognised techniques, for the full dynamic system formed by the oil engines, turbines, motors, generators, flexible couplings, gearing, shafting and propeller, where applicable, including all branches.

2.3.2 Calculations are to give due consideration to the potential deviation in values used to represent component characteristics due to manufacturing/service variability.

2.3.3 The calculations carried out on oil engine systems are to be based on the Enginebuilders' harmonic torque data. The calculations are to take account of the effects of engine malfunctions commonly experienced in service, such as a cylinder not firing (i.e., no injection but with compression) giving rise to the highest torsional vibration stresses in the shafting. Calculations are also to take account of a degree of imbalance between cylinders, which is characteristic of the normal operation of an engine under service conditions.

2.3.4 Whilst limits for torsional vibration stress in crankshafts are no longer stated explicitly, calculations are to include estimates of crankshaft stress at all designated operating/service speeds, as well as at any major critical speed.

2.3.5 Calculations are to take into account the possible effects of excitation from propeller rotation. Where the system shows some sensitivity to this phenomenon, propeller excitation data for the installation should be used as a basis for calculation, and submitted.

2.3.6 Where the torsional stiffness of flexible couplings varies with torque, frequency or speed, calculations should be representative of the appropriate range of effective dynamic stiffness.

2.4 Symbols and definitions

2.4.1 The symbols used in this Section are defined as follows:

d = minimum diameter of shaft considered, in mm
d_i = diameter of internal bore, in mm
k = the factor used in determining minimum shaft diameter, defined in Ch 6,3.1.1 and 3.5.1
r = ratio N/N_s or N_c/N_s, whichever is applicable
C_d = a size factor defined as $0{,}35 + 0{,}93d^{-0{,}2}$
C_k = a factor for different shaft design features, *see* Table 8.2.1
N = engine speed, in rev/min
N_c = critical speed, in rev/min
N_s = maximum continuous engine speed, in rev/min, or, in the case of constant speed generating sets, the full load speed, in rev/min
Q_s = rated full load mean torque
σ_u = specified minimum tensile strength of the shaft material, in N/mm^2
τ_c = permissible stress due to torsional vibrations for continuous operation, in N/mm^2
τ_t = permissible stress due to torsional vibrations for transient operation, in N/mm^2
e = slot width, in mm
l = slot length, in mm.

Table 8.2.1 C_k factors

Intermediate shafts with	
Integral coupling flange and straight sections	1,0
Shrink fit coupling	1,0
Keyway, tapered connection	0,60
Keyway, cylindrical connection	0,45
Radial hole	0,50
Longitudinal slot	0,30 (*see* 2.4.4)
Thrust shafts external to engines	
On both sides of thrust collar	0,85
In way of axial bearing where a roller bearing is used as a thrust bearing	0,85
Propeller shafts	
Flange mounted or keyless taper fitted propellers	0,55
Key fitted propellers	0,55
Between forward end of aft most bearing and forward stern tube seal	0,80
NOTE The determination of C_k – factors for shafts other than shown in this Table will be specially considered by LR.	

2.4.2 Alternating torsional vibration stresses are to be based on half-range amplitudes of stress resulting from the alternating torque (which is superimposed on the mean torque) representing the synthesis of all harmonic orders present.

2.4.3 All vibration stress limits relate to the synthesis or measurement of total nominal torsional stress and are to be based on the plain section of the shafting neglecting stress raisers.

2.4.4 For a longitudinal slot, C_k = 0,3 is applicable within the dimension limitations given in Pt 5, Ch 6,3.1.6. If the slot dimensions are outside these limitations, or if the use of another C_k is desired, the actual stress concentration factor (*scf*) is to be documented or determined from 2.4.5, in which case:

$$C_k = \frac{1{,}45}{scf}$$

Note that the *scf* is defined as the ratio between the maximum local principal stress and $\sqrt{3}$ times the nominal torsional stress (determined for the bored shaft without slots).

2.4.5 **Stress concentration factor of slots**. The stress concentration factor (*scf*) at the ends of slots can be determined by means of the following empirical formulae:

$$scf = \alpha_{t(hole)} + 0{,}57 \frac{\frac{(l - e)}{d}}{\sqrt{\left(1 - \frac{d_i}{d}\right) \frac{e}{d}}}$$

This formula applies to:

- Slots at 120 or 180 or 360 degrees apart.
- Slots with semi-circular ends. A multi-radii slot end can reduce the local stresses, but this is not included in this empirical formula.
- Slots with no edge rounding (except chamfering), as any edge rounding increases the *scf* slightly.

$\alpha_{t(hole)}$ represents the stress concentration of radial holes and can be determined as :

$$\alpha_{t(hole)} = 2{,}3 - 3 \frac{e}{d} + 15 \left(\frac{e}{d}\right)^2 + 10 \left(\frac{e}{d}\right)^2 \left(\frac{d_i}{d}\right)^2$$

where

e = hole diameter, in mm

or simplified to $\alpha_{t(hole)} = 2{,}3$.

2.5 Limiting stress in propulsion shafting

2.5.1 The following stress limits apply to intermediate shafts, thrust shafts and to screwshafts fully protected from sea-water. For screwshafts, the limits apply to the minimum sections of the portions of the screwshaft as defined in Ch 6,3.5.

2.5.2 In the case of unprotected screwshafts, special consideration will be given.

2.5.3 In no part of the propulsion shafting system may the alternating torsional vibration stresses exceed the values of τ_c for continuous operation, and τ_t for transient running, given by the following formulae:

$$\tau_c = \pm \frac{\sigma_u + 160}{18} C_k C_d \left(3 - 2r^2\right) \text{ for } r < 0{,}9 \quad \text{N/mm}^2$$

$$\tau_c = \pm \frac{\sigma_u + 160}{18} C_k C_d\, 1{,}38 \text{ for } 0{,}9 \le r \le 1{,}05 \quad \text{N/mm}^2$$

$$\tau_t = \pm \frac{1{,}7 \tau_c}{\sqrt{C_k}} \quad \text{for } r \le 0{,}8 \quad \text{N/mm}^2$$

2.5.4 In general, the tensile strength of the steel used is to comply with the requirements of Ch 6,2. For the calculation of the permissible limits of stresses due to torsional vibration, σ_u is not to be taken as more than 800 N/mm^2 in the case of alloy steel intermediate shafts, or 600 N/mm^2 in the case of carbon and carbon-manganese steel intermediate thrust and propeller shafts.

2.5.5 Where the scantlings of coupling bolts and straight shafting differ from the minimum required by the Rules, special consideration will be given.

2.6 Generator sets

2.6.1 Natural frequencies of the complete set are to be sufficiently removed from the firing impulse frequency at the full load speed, particularly where flexible couplings are interposed between the engine and generator.

2.6.2 Within the speed limits of $0{,}95N_s$ and $1{,}05N_s$ the vibration stresses in the transmission shafting are not to exceed the values given by the following formula:

$$\tau_c = \pm (21 - 0{,}014d) \quad \text{N/mm}^2.$$

2.6.3 Vibration stresses in the transmission shafting, due to critical speeds which have to be passed through in starting and stopping, are not to exceed the values given by the following formula:

$$\tau_t = 5{,}5\tau_c.$$

2.6.4 The amplitudes of the total vibratory inertia torques imposed on the generator rotors are to be limited to $\pm 2{,}0Q_s$ in general, or to $\pm 2{,}5Q_s$ for close-coupled revolving field alternating current generators, over the speed range from $0{,}95N_s$ to $1{,}05N_s$. Below $0{,}95N_s$ the amplitudes are to be limited to $\pm 6{,}0Q_s$. Where two or more generators are driven from one engine, each generator is to be considered separately in relation to its own rated torque.

2.6.5 The rotor shaft and structure are to be designed to withstand these magnitudes of vibratory torque. Where it can be shown that they are capable of withstanding a higher vibratory torque, special consideration will be given.

2.6.6 In addition to withstanding the vibratory conditions over the speed range from $0{,}95N_s$ to $1{,}05N_s$, flexible couplings, if fitted, are to be capable of withstanding the vibratory torques and twists arising from transient criticals and short-circuit currents.

2.6.7 In the case of alternating current generators, resultant vibratory amplitudes at the rotor are not to exceed ±3,5 electrical degrees under both full load working conditions and the malfunction condition mentioned in 2.3.3.

2.7 Other auxiliary machinery systems

2.7.1 The relevant requirements of 2.6.1, 2.6.2 and 2.6.3 are also applicable to other machinery installations such as pumps or compressors, with the speed limits being taken as $0{,}95N_s$ to $1{,}10N_s$.

2.8 Other machinery components

2.8.1 **Torsional vibration dampers**. The use of dampers or detuners to limit vibratory stress due to resonances which occur within the range between $0{,}85N_s$ and $1{,}05N_s$ are to be considered. If fitted, these should be of a type which makes adequate provision for dissipation of heat. Where necessary, performance monitoring may be required.

2.8.2 **Flexible couplings**:

(a) Flexible couplings included in an installation are to be capable of transmitting the mean and vibratory loads without exceeding the makers' recommended limits for angular amplitude or heat dissipation.

(b) Where calculations indicate that the limits recommended by the manufacturer may be exceeded under misfiring conditions, a suitable means is to be provided for detecting and indicating misfiring. Under these circumstances power and/or speed restrictions may be required. Where machinery is non-essential, disconnection of the branch containing the coupling would be an acceptable action in the event of misfiring.

2.8.3 **Gearing**:

(a) The torsional vibration characteristics are to comply with the requirements of 2.3. The sum of the mean and of the vibratory torque should not exceed four-thirds of the full transmission torque, at MCR, throughout the speed range. In cases where the proposed transmission torque loading on the gear teeth is less than the maximum allowable, special consideration will be given to the acceptance of additional vibratory loading on the gears.

(b) Where calculations indicate the possibility of torque reversal, the operating speed range is to be determined on the basis of observations during sea trials.

2.9 Measurements

2.9.1 Where calculations indicate that the limits for torsional vibration within the range of working speeds are exceeded, measurements, using an appropriate technique, may be taken from the machinery installation for the purpose of approval of torsional vibration characteristics, or determining the need for restricted speed ranges, and the confirmation of their limits.

2.9.2 Where differences between calculated and measured levels of stress, torque or angular amplitude arise, the stress limits are to be applied to the stresses measured on the completed installation.

2.9.3 The method of measurement is to be appropriate to the machinery components and the parameters which are of concern. Where shaft stresses have been estimated from angular amplitude measurements, and are found to be close to limiting stresses as defined in 2.5, strain gauge techniques may be required. When measurements are required, detailed proposals are to be submitted.

2.10 Vibration monitoring

2.10.1 Where calculations and/or measurements have indicated the possibility of excessive vibratory stresses, torques or angular amplitudes in the event of a malfunction, vibration or performance monitoring, directly or indirectly, may be required.

2.11 Restricted speed and/or power ranges

2.11.1 Restricted speed and/or power ranges will be imposed to cover all speeds where the stresses exceed the limiting values, τ_c, for continuous running, including one-cylinder misfiring conditions if intended to be continuously operated under such conditions. For controllable pitch propellers with the possibility of individual pitch and speed control, both full and zero pitch conditions are to be considered. Similar restrictions will be imposed, or other protective measures required to be taken, where vibratory torques or amplitudes are considered to be excessive for particular machinery items. At each end of the restricted speed range the engine is to be stable in operation.

2.11.2 The restricted speed range is to take account of the tachometer speed tolerances at the barred speeds.

2.11.3 Critical responses which give rise to speed restrictions are to be arranged sufficiently removed from the maximum revolutions per minute to ensure that, in general, at r = 0,8 the stress due to the upper flank does not exceed τ_c.

2.11.4 Provided that the stress amplitudes due to a torsional critical response at the borders of the barred speed range are less than τ_c under normal and stable operating conditions the speed restriction derived from the following formula may be applied:

$$\frac{16}{18-r} N_c \text{ to } \frac{18-r}{16} N_c \text{ inclusive.}$$

2.11.5 Where calculated vibration stresses due to criticals below $0{,}8N_s$ marginally exceed τ_c or where the critical speeds are sharply tuned, the range of revolutions restricted for continuous operation may be reduced.

2.11.6 In cases where the resonance curve of a critical speed has been derived from measurements, the range of revolutions to be avoided for continuous running may be taken as that over which the measured vibration stresses are in excess of τ_c, having regard to the tachometer accuracy.

2.11.7 Where restricted speed ranges under normal operating conditions are imposed, notice boards are to be fitted at the control stations stating that the engine is not to be run continuously between the speed limits obtained as above, and the engine tachometers are to be marked accordingly.

2.11.8 Where vibration stresses approach the limiting value, τ_t, the range of revolutions restricted for continuous operation may be extended. The notice boards are to indicate that this range must be passed through rapidly.

2.11.9 For excessive vibratory torque, stress or amplitude in other components, based on 2.8.1 to 2.8.3, the limits of any speed/power restriction are to be such as to maintain acceptable levels during continuous operation.

2.11.10 Where the restrictions are imposed for the contingency of an engine malfunction or component failure, the limits are to be entered in the machinery Operating Manual.

2.11.11 Restricted speed ranges in one-cylinder misfiring conditions on units with single engine propulsion are to enable safe navigation whereby sufficient propulsion power is available to maintain control of the unit.

2.11.12 There are to be no restricted speed ranges imposed above a speed ratio of r = 0,8 under normal operating conditions.

2.12 Tachometer accuracy

2.12.1 Where restricted speed ranges are imposed as a condition of approval, the tachometer accuracy is to be checked against the counter readings, or by equivalent means, in the presence of the Surveyors to verify that it reads correctly within ± 2 per cent in way of the restricted range of revolutions.

2.13 Governor control

2.13.1 Where there is a significant critical response above and close to the maximum service speed, consideration is to be given to the effect of temporary overspeed.

■ *Section 3* Axial vibration

3.1 General

3.1.1 For all main propulsion shafting systems, the Builders are to ensure that axial vibration amplitudes are satisfactory throughout the speed range. Where natural frequency calculations indicate significant axial vibration responses, sufficiently wide restricted speed ranges will be imposed. Alternatively, measurements may be used to determine the speed ranges at which amplitudes are excessive for continuous running.

3.2 Particulars to be submitted

3.2.1 The results of calculations, together with recommendations for any speed restrictions found necessary.

3.2.2 Enginebuilder's recommendation for axial vibration amplitude limits at the non-driving end of the crankshaft or at the thrust collar.

3.2.3 Estimate of flexibility of the thrust bearing and its supporting structure.

3.2.4 The requirement for calculations to be submitted may be waived upon request provided evidence of satisfactory service experience of similar dynamic installations is submitted.

3.3 Calculations

3.3.1 Calculations of axial vibration natural frequency are to be carried out using appropriate techniques, taking into account the effects of flexibility of the thrust bearing, for shaft systems where the propeller is:

(a) Driven directly by a reciprocating internal combustion engine.

(b) Driven via gears, or directly by an electric motor, and where the total length of shaft between propeller and thrust bearing is in excess of 60 times the intermediate shaft diameter.

3.3.2 Where an axial vibration damper is fitted, the calculations are to consider the effect of a malfunction of the damper.

3.3.3 For those systems as defined in 3.3.1(b) the propeller speed at which the critical frequency occurs may be estimated using the following formula:

$$\frac{0{,}98}{N}\left(\frac{ab}{a+b}\right)^{1/2} \quad \text{rev/min}$$

where

$$a = \frac{E}{G\,l^2}\,(66{,}2 + 97{,}5A - 8{,}88A^2)^2 \quad (\text{c/min})^2$$

$$b = 91{,}2\,\frac{k}{M_e} \quad (\text{c/min})^2$$

d = internal diameter of shaft, in mm
k = estimated stiffness at thrust block bearing, in N/m
l = length of shaft line between propeller and thrust bearing, in mm
m = mass of shaft line considered, in kg
= $0{,}785\,(D^2 - d^2)\,G\,l$

$A = \dfrac{m}{M}$

D = outside diameter of shaft, taken as an average over length l, in mm
E = modulus of elasticity of shaft material, in N/mm^2
G = density of shaft material, in kg/mm^3
M = dry mass of propeller, in kg
M_e = $M\,(A + 2)$
N = number of propeller blades

Where the results of this method indicate the possibility of an axial vibration resonance in the vicinity of the maximum service speed, calculations using a more accurate method will be required.

3.4 Measurements

3.4.1 Where calculations indicate the possibility of excessive axial vibration amplitudes within the range of working speeds under normal or malfunction conditions, measurements are required to be taken from the shafting system for the purpose of determining the need for restricted speed ranges.

3.5 Restricted speed ranges

3.5.1 The limits of any speed restriction are to be such as to maintain axial amplitudes within recommended levels during continuous operation.

3.5.2 Limits of a speed restriction, where required, may be determined by calculation or on the basis of measurement.

3.5.3 Where a speed restriction is imposed for the contingency of a damper malfunction, the speed limits are to be entered in the machinery Operating Manual and regular monitoring of the axial vibration amplitude is required. Details of proposals for monitoring are to be submitted.

3.6 Vibration monitoring

3.6.1 Where a vibration monitoring system is to be specified, details of proposals are to be submitted.

■ *Section 4* Lateral vibration

4.1 General

4.1.1 For all main propulsion shafting systems, the Builders are to ensure that lateral vibration characteristics are satisfactory throughout the speed range.

4.2 Particulars to be submitted

4.2.1 Calculations of the lateral vibration characteristics of shafting systems having supports outboard of the hull or incorporating cardan shafts are to be submitted.

4.3 Calculations

4.3.1 The calculations in 4.2.1, taking account of bearing, oil-film (where applicable) and structural dynamic stiffnesses, are to investigate the excitation frequencies giving rise to all critical speeds which may result in significant amplitudes within the speed range, and are to indicate relative deflections and bending moments throughout the shafting system.

4.3.2 The calculated natural frequencies of the system are to be compared to both the shaft rotational orders and propeller blade passing frequencies. Where cardan shafts are fitted, the shaft second rotational orders are also to be considered.

4.3.3 Requirements for calculations may be waived upon request provided evidence of satisfactory service experience of similar dynamic installations is submitted.

4.4 Measurements

4.4.1 Where calculations indicate the possibility of significant lateral vibration responses within the range of ±20 per cent of the M.C.R. speed, measurements using an appropriate recognised technique may be required to be taken from the shafting system for the purpose of determining the need for restricted speed ranges.

4.4.2 The method of measurement is to be appropriate to the machinery arrangement and the modes of vibration which are of concern. When measurements are required, detailed proposals are to be submitted in advance.

■ *Section 5* Shaft alignment

5.1 General

5.1.1 Shaft alignment calculations are to be carried out for main propulsion shafting rotating at propeller speed, including the crankshaft of direct drive systems or the final reduction gear wheel on geared installations. The Builder is to make available shaft alignment procedures detailing the proposed alignment method and checks for these arrangements.

5.2 Particulars to be submitted for approval – shaft alignment calculations

5.2.1 Shaft alignment calculations are to be submitted to LR for approval for the following shafting systems:

(a) All geared installations, where the screwshaft has a diameter of 300 mm or greater in way of the aftmost bearing.
(b) All direct drive installations which incorporate 3 or less bearings supporting the intermediate and screwshaft aft of the prime mover.
(c) Where prime movers or shaftline bearings are installed on resilient mountings.
(d) All systems where the screwshaft has a diameter of 800 mm or greater in way of the aftmost bearing.

5.2.2 The shaft alignment calculations are to take into account the:

(a) thermal displacements of the bearings between cold static and hot dynamic machinery conditions;
(b) buoyancy effect of the propeller immersion due to the unit's operating draughts;
(c) effect of predicted hull deformations over the range of the unit's operating draughts, where known;
(d) effect of filling the aft peak ballast tank upon the bearing loads, where known;
(e) gear forces, where appropriate, due to prime-mover engagement on multiple-input single-output installations;
(f) propeller offset thrust effects;
(g) maximum allowed bearing weardown, for water or grease-lubricated sterntube bearings, and its effect on the bearing loads.

5.2.3 The shaft alignment calculations are to state the:

(a) expected bearing loads at light and normal ballast, fully loaded and any other draughts deemed to be part of the unit's operating profile, for the machinery in cold and hot, static and dynamic conditions;
(b) bearing influence coefficients and the deflection, slope, bending moment and shear force along the shaftline;
(c) details of propeller offset thrust;
(d) details of proposed slope-bore of the aftermost sterntube bearing, where applicable;
(e) manufacturer's specified limits for bending moment and shear force at the shaft couplings of the gearbox/prime movers;
(f) estimated bearing weardown rates for water or grease-lubricated sterntube bearings;
(g) expected hull deformation effects and their origin, *viz*. whether finite element calculations or measured results from sister or similar units have been used;
(h) anticipated thermal rise of prime movers and gearing units between cold static and hot running conditions; and
(j) manufacturer's allowable bearing loads.

5.3 Shaft alignment procedures

5.3.1 A shaft alignment procedure is to be made available for review and for the information of the attending surveyors for all main propulsion installations detailing, as a minimum,

(a) expected bearing loads at light and normal ballast, fully loaded and any other draughts deemed to be part of the unit's operating profile, for the machinery in cold and hot, static and dynamic conditions;
(b) maximum permissible loads for the proposed bearing designs;
(c) design bearing offsets from the straight line;
(d) design gaps and sags;
(e) location and loads for the temporary shaft supports;
(f) expected relative slope of the shaft and the bearing in the aftermost sterntube bearing;
(g) details of slope-bore of the aftermost sterntube bearing, where applied;
(h) proposed bearing load measurement technique and its estimated accuracy;
(j) jack correction factors for each bearing where the bearing load is measured using a specified jacking technique;
(k) proposed shaft alignment acceptance criteria, including the tolerances; and
(l) flexible coupling alignment criteria.

5.4 Design and installation criteria

5.4.1 For main propulsion installations, the shafting is to be aligned to give, in all conditions of unit loading and machinery operation, bearing load distribution satisfying the requirements of 5.4.2.

5.4.2 Design and installation of the shafting is to satisfy the following criteria:

(a) The Builder is to position the bearings and construct the bearing seatings to minimise the effects of hull deflections under any of the unit's operating conditions with the aim of optimising the bearing load distribution.
(b) Relative slope between the propeller shaft and the aftermost sterntube bearing is, in general, not to exceed 3×10^{-4} rad in the static condition.
(c) Sterntube bearing loads are to satisfy the requirements of Ch 6,3.12.
(d) Evidence is to be provided to LR demonstrating that bearings of synthetic material have been verified as being within the tolerance stated by the bearing manufacturer for diameter, ovality, and straightness after installation.
(e) Bearings of synthetic material are to be verified as being within tolerance for ovalilty and straightness, circumferentially and longitudinally, after installation.
(f) The sterntube forward bearing static load is to be sufficient to prevent unloading in all static and dynamic operating conditions, including the transient conditions experienced during manoeuvring turns and during operation in heavy weather.
(g) Intermediate shaft bearings' loads are not to exceed 80 per cent of the bearing manufacturer's allowable maximum load, for plain journal bearings, based on the bearing projected area.
(h) Equipment manufacturer's bearing loads are to be within the manufacturer's specified limits, i.e., prime movers, gearing.
(j) Resulting shear forces and bending moments are to meet the equipment manufacturer's specified coupling conditions.
(k) The manufacturer's radial, axial and angular alignment limits for the flexible couplings are to be maintained.

5.5 Measurements

5.5.1 The system bearing load measurements are to be carried out to verify that the design loads have been achieved. In general the measurements will be carried out by the jack-up measurement technique using calibrated equipment.

5.5.2 For the first vessel of a new design an agreed programme of static shaft alignment measurements is to be carried out in order to verify that the shafting has been installed in accordance with the design assumptions and to verify the design assumptions in respect of the hull deflections and the effects of machinery temperature changes. The programme is to include static bearing load measurements in a number of selected conditions. Depending on the unit type and the operational loading conditions that are achievable prior to and during sea trials these should include, where practicable, combinations of light ballast cold, full ballast cold, full ballast hot and full draught hot with aft peak tank empty and full.

5.5.3 For vessels of an existing design or similar to an existing design where evidence of satisfactory service experience is submitted for consideration and for subsequent units in a series a reduced set of measurements may be accepted. In such cases the minimum set of measurements is to be sufficient to verify that the shafting has been installed in accordance with the design assumptions and are to include at least one cold and one hot representative condition.

5.5.4 Where calculations indicate that the system is sensitive to changes in alignment under different service conditions, the shaft alignment is to be verified by measurements during sea trials using an approved strain gauge technique.

5.6 Flexible couplings

5.6.1 Where the shafting system incorporates flexible couplings, the effects of such couplings on the various modes of vibration are to be considered, *see* Sections 2, 3 and 4.

Section

■ *Section 1* Scope

1.1 General

1.1.1 This Chapter applies to podded propulsion units where used for propulsion, dynamic positioning duty or as the sole means of steering.

1.1.2 For the purposes of these Rules, a podded propulsion unit is any propulsion or manoeuvring device that is external to the normal form of the unit's hull and houses a propeller powering device.

1.1.3 The requirements of this Chapter relate to podded propulsion units powered by electric propulsion motors, (and are in addition to the requirements for Electric Propulsion in Pt 6, Ch 2,16 and other relevant Sections). Podded propulsion units with other drive arrangements will be subject to individual consideration.

1.1.4 The structural requirements stated in 5.1, 5.2 and 5.3 relate to podded propulsion units having a pod body with single supporting strut with or without an integral slewing ring arrangement, *see* Fig. 9.1.1. Novel and unconventional arrangements will be subject to individual consideration. In such cases, the designers are advised to contact LR in the early stages of the design for advice on the manner and content of design information required for formal classification appraisal.

1.1.5 The aft end structures associated with podded installations are to be examined with respect to potential slamming, *see* Pt 4, Ch 3,4.1.5.

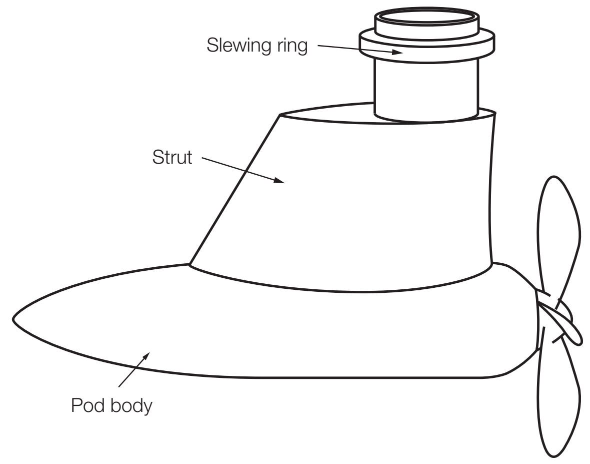


Fig. 9.1.1 Podded propulsion unit

1.1.6 It is the builder's responsibility to ensure that all installed equipment is suitable for operation in the location and under all anticipated environmental conditions associated with the design of the unit which is to include temperature, humidity, vibration and impulsive accelerations.

1.1.7 The design of a podded propulsor system is to take into account a range of operating conditions which are to include the following:

- All ahead seagoing conditions up to and including the maximum rated output of the podded propulsor while maintaining a steady course under foreseeable sea and wind conditions.
- The ability of the unit to change direction rapidly at the declared steering angles with the unit running at maximum ahead service speed.
- Executing a steady turning manoeuvre with a tactical diameter not greater than 5*L* and advance not greater than 4,5*L* whilst maintaining a power corresponding to the test speed, where *L* is the length measured between the aft and forward perpendiculars. Test speed is defined as a speed of at least 90 per cent of the unit's speed corresponding to 85 per cent of the maximum rated power of the podded propulsor.
- Changing heading, manoeuvring in and out of harbour both ahead and astern, at slow speeds, stationary and starting from rest in foreseeable current and wind conditions.
- Berthing manoeuvres in the case of azimuthing podded propulsion units.
- Rapid acceleration and deceleration manoeuvres where the unit's operating profile demands this capability.
- Holding stationary positions over-ground under different conditions.
- Stopping manoeuvre as required by Ch 1,5.2.
- Manoeuvring in ice where ice class is required.

Section 2
General requirements

2.1 Pod arrangement

2.1.1 In general, for a unit to be assigned an unrestricted service notation, a minimum of two podded propulsion units are to be provided where these form the sole means of propulsion. For vessels where a single podded propulsion unit is the sole means of propulsion, an evaluation of a detailed engineering and safety justification will be conducted by LR, *see* 2.2.2. This evaluation process will include the appraisal of a Failure Modes and Effects Analysis (FMEA) to verify that sufficient levels of redundancy and monitoring are incorporated in the podded propulsion unit's essential support systems and operating equipment.

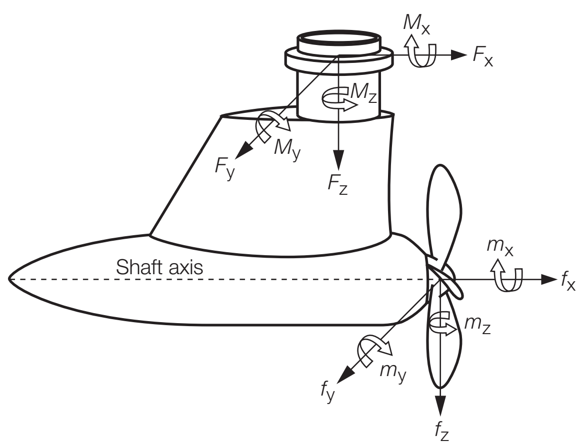


Fig. 9.2.1 Pod co-ordinate system

2.2 Plans and information to be submitted

2.2.1 In addition to the plans required by Chapters 5, 6, 7, 8, 14 and 19, and Pt 6, Ch 1 and Ch 2, the following plans and information are required to be submitted for appraisal:

(a) Description of the unit's purpose/capabilities together with the pod's intended operational modes in support of these capabilities.
(b) Power transmitted at MCR condition (shaft power and rpm) and other maximum torque conditions, e.g., bollard pull.
(c) Maximum transient thrust, torque and other forces and moments experienced during all envisaged operating modes as permitted by the steering and propulsor drive control systems.
(d) Details of the electric propulsion motor short-circuit torque and motor air gap tolerance.
(e) Sectional assembly in the Z-X plane, *see* Fig. 9.2.1.
(f) Specifications of materials and NDE procedures for components essential for propulsion and steering operation to include propulsion shaft and slewing ring bearings, gearing and couplings, *see* 4.1.
(g) Details of intended manoeuvring capability of the unit in each operating condition. (To be declared by the shipyard, *see also* 3.1.1).
(h) Design loads for both the pod structure and propeller together with podded propulsion unit design operating modes, *see* 2.4.1, 6.3.7, 6.6.5 and 6.6.6.
(j) Supporting data and direct calculation reports. This is to include, where applicable, an assessment of anticipated global accelerations acting on the unit's machinery and equipment which may potentially affect the reliable operation of the propulsion system for all foreseeable seagoing and operating conditions. Typically, this may include response to slamming, extreme unit motions and pod interaction. *See also* 1.1.5.
(k) Structural component details including: strut, pod body, bearing supports, bearing end caps, unit's structure in way of podded propulsion unit integration and a welding Table showing a key to weld symbols used on the plans specifying weld size, type, preparation and heat treatment. The information should include the following:
  - Detailed drawings showing the structural arrangement, dimensions and scantlings.
  - Welding and structural details.
  - Connections between structural components (bolting).
  - Casting's chemical and mechanical properties.
  - Forging's chemical and mechanical properties.
  - Material grades for plate and sections.
(l) Nozzle structure, its support arrangements, together with related calculations for all permitted operating conditions where the propeller operates in a nozzle (duct), *see* Pt 3, Ch 13,3 of the Rules for Ships.
(m) Propeller shaft bearing mounting and housing arrangement details, *see also* 6.3.6.
(n) Details of propeller shaft and steering bearings, where roller bearings are used supporting calculations are to be submitted, *see* 6.3.7 and 6.6.6.
(o) Propeller shaft seal details.
(p) Details of propeller shaft and pod steering securing/locking and means of aligning the securing/locking arrangements.
(q) Cooling systems piping system schematic.
(r) Details of any lubricating oil conditioning systems (filtering/cooling/heating) and control arrangements necessary to ensure the continuous availability of the required lubricating oil quality to the propeller shaft bearings.
(s) Details of installed condition monitoring equipment.
(t) Details of the derivation of any duty factor used in the design of the steering gears.
(u) Identification of any potentially hazardous atmospheric conditions together with details of how the hazard will be countered, this should include a statement of the maximum anticipated air temperature within the pod during full power steady state operation, *see* 2.3.
(v) Where provided, access and closing arrangements for pod unit inspection and maintenance.
(w) Heat balance calculations for pods having an electric propulsion motor but no active cooling system, *see* 6.7.4.
(x) Details of proposed testing and trials required by Section 9.
(y) Details of emergency steering and pod securing arrangements. *See* 6.3.11.
(z) Quality plan for electronic control systems and electrical actuating systems.

2.2.2 Where an engineering and safety justification report is required, the following supporting information is to be submitted:

- A Failure Mode and Effects Analysis (FMEA), *see* 2.5.
- Design standards and assumptions.
- Limiting operating parameters.
- A statement and evidence in respect of the anticipated reliability of any non-duplicated components.

2.2.3 Recommended installation, inspection, maintenance and component replacement procedures (*see also* 5.1.2). This is to include any in-water/underwater engineering procedures where recommended by the pod manufacturer. *See also* 6.5.7 and Section 10.

2.3 Pod internal atmospheric conditions

2.3.1 Machinery and electrical equipment installed within the pod unit are to be suitable for operation, without degraded performance, at the maximum anticipated air temperature and humidity conditions within the pod unit with the pod operating at its maximum continuous rating in sea water of not less than 32°C after steady state operating conditions have been achieved.

2.3.2 Precautions are to be taken to prevent as far as reasonably practicable the possibility of danger to personnel and damage to equipment arising from the development of hazardous atmospheric conditions within the pod unit. Circumstances that may give rise to these conditions are to be identified and the counter measures taken are to be defined.

2.4 Global loads

2.4.1 The overall strength of the podded propulsion unit structure is to be based upon the maximum anticipated in-service loads, including the effects of manoeuvring and motion of the unit (*see* Table 14.8.1 in Pt 3, Ch 14). This is to include the effects of any pod to unit and/or pod to unit hydrodynamic interference effects. The designer is to supply the following maximum load and moment values to which the unit may be subjected with a description of the operating condition at which they occur.

- F_x, Force in the longitudinal direction;
- F_y, Force in the transverse direction;
- F_z, self weight, in water, augmented by the unit's pitch and heave motion and flooded volume where applicable, *see* Pt 3, Ch 14;
- M_x, moment at the slewing ring about the pod unit's global longitudinal axis;
- M_y, moment at the slewing ring about the pod unit's global transverse axis;
- M_z, moment at the slewing ring about the pod unit's vertical axis (maximum dynamic duty steering torque on steerable pods).

The directions of the X, Y and Z axes, with the origin at the centre of the slewing ring, are shown in Fig. 9.2.1.

2.4.2 Where the maximum forces and moments defined in 2.4.1 cannot be accurately calculated, then, an estimate of these loadings is to be stated together with an assessment of the associated error tolerances for the sequences of permitted design manoeuvres, *see* 1.1.7. Typically this will include emergency astern manoeuvres, zig zag manoeuvres and pod interaction. Such estimates are to be defined on a load versus pod angle basis. In the case of pod to pod and/or pod to unit hydrodynamic interaction effects these, must be defined for the most severely affected propulsor.

2.4.3 Where control systems are installed to limit the operation of the podded drive to defined angles at defined unit speeds, this information may be taken into consideration when determining the pod unit loading.

2.4.4 Where pod units are fixed about their Z axis, then maximum global loads, to be used as the basis of the structural appraisal, are to be determined for inflows in 5 degree increments between the extremes of anticipated inflow angle during manoeuvring with unit at full speed and maximum propeller thrust.

2.4.5 The podded propulsor is to be capable of with-standing a blade root failure due to fatigue occurring at the maximum rated output of the podded propulsor without initiating a failure in other parts of the propulsor system.

2.5 Failure Modes and Effects Analysis (FMEA)

2.5.1 An FMEA is to be carried out where a single podded propulsion unit is the vessel's sole means of propulsion, *see* 2.1.1. The FMEA is to identify components where a single failure could cause loss of all propulsion and/or steering capability and the proposed arrangements for preventing and mitigating the effects of such a failure.

2.5.2 The FMEA is to be carried out using the format presented in Table 22.2.1 in Chapter 22 or an equivalent format that addresses the same reliability issues. Analyses in accordance with IEC 60812, *Analysis techniques for system reliability – Procedure for failure mode and effects analysis (FMEA)*, or IMO MSC Resolution 36(63) Annex 4 – *Procedures for Failure Mode and Effects Analysis*, would be acceptable.

2.5.3 The FMEA is to be organised in terms of equipment and function. The effects of item failures at a stated level and at higher levels are to be analysed to determine the effects on the system as a whole. Actions for mitigation of the effects of failure are to be determined, *see* 2.5.1.

2.5.4 The FMEA is to:

(a) identify the equipment or sub-system and mode of operation;
(b) identify potential failure modes and their causes;
(c) evaluate the effects on the system of each failure mode;
(d) identify measures for reducing the risks associated with each failure mode;
(e) identify measures for preventing failure; and
(f) identify trials and testing necessary to prove conclusions.

2.5.5 At sub-system level it is acceptable, for the purpose of these Rules, to consider failure of equipment items and their functions, e.g., failure of a pump to produce flow or pressure head. It is not required that the failure of components within that pump be analysed. In addition, their failure need only be dealt with as a cause of failure of the pump.

2.5.6 Where FMEA is used for consideration of systems that depend on software-based functions for control or co-ordination, the analysis is to investigate failure of the functions rather than a specific analysis of the software code itself.

2.6 Ice Class requirements

2.6.1 Where an ice class notation is included in the class of a unit, additional requirements as detailed in Part 8 are to be complied with as applicable.

■ *Section 3* Functional capability

3.1 General

3.1.1 The arrangement of podded propulsion units is to be such that the unit can be satisfactorily manoeuvred to a declared performance capability. The operating conditions covered are to include the following:

(a) Maximum continuous shaft power/speed to the propeller in the ahead condition at the declared steering angles and sea conditions.
(b) Manoeuvring speeds of the propeller shaft in the ahead and astern direction at the declared steering angles and sea conditions.
(c) The stopping manoeuvre described in Ch 1,5.2.2(b).
(d) All astern running conditions for the unit.
(e) Manoeuvring in ice where ice class is required.

3.1.2 In general, the steering mechanism is to be capable of turning the pod between the declared steering angle limits, at an average rotational speed of not less than 0,4 rev/min, with the unit initially operating at its maximum ahead service speed.

3.1.3 The steering mechanism for podded units used for Dynamic Positioning applications with an associated class notation, is to be capable of a rotational speed of not less than 1,5 rev/min.

■ *Section 4* Materials

4.1 General

4.1.1 The materials used for major structural and machinery components are to be manufactured and tested in accordance with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials). These components include hull support structure, pod body, pod strut, shafting and propellers.

4.1.2 Components of novel design or components manufactured from materials not covered by the Rules for Materials are to be subject to evaluation and approval by Lloyd's Register (hereinafter referred to as 'LR') prior to manufacture.

4.1.3 Material specifications, *see* 2.2.1(f), for propulsion shaft and slewing ring bearings, gearing and couplings are to be approved by LR prior to manufacture. The specification is to include details of the grade of material, including the target range of chemical composition that is to be reported on the certificate, the required mechanical properties, heat treatment details including temperatures and hold times, details of necessary non-destructive examinations including acceptance levels. Additionally, any steel cleanness or microstructure requirements are to be included. These components are to be manufactured under survey.

4.1.4 For propulsion shaft rolling element bearings, the amount of retained austenite is to be determined and is not to exceed 4 per cent for nominally bainitic structures.

4.1.5 Where load carrying threaded fasteners screw directly into structural castings, the integrity of the casting is to be such that there is no porosity or shrinkage in the area of the connection.

■ *Section 5* Structure design and construction requirements

5.1 Pod structure

5.1.1 Podded unit struts and pod bodies may be of cast, forged or fabricated construction or a combination of these construction methods.

5.1.2 Means are to be provided to enable the shaft, bearings and seal arrangements to be examined in accordance with LR's requirements and the manufacturer's recommendations.

5.1.3 When high tensile steel fasteners are used as part of the structural arrangement and there is a risk that these fasteners may come into contact with sea-water, carbon-manganese and low alloy steels with a specified tensile strength of greater than 950 N/mm^2 are not to be used due to the risk of hydrogen embrittlement.

5.1.4 For steerable pod units, an integral slewing ring is to be arranged at the upper extremity of the strut to provide support for the slewing bearing.

5.1.5 The strut is to have a smooth transition from the upper mounting to the lower hydrodynamic sections.

5.1.6 For fabricated structures, vertical and horizontal plate diaphragms are to be arranged within the strut and, where necessary, secondary stiffening members are to be arranged.

5.1.7 Pod unit structure scantling requirements are shown in Table 9.5.1. Where the scantling requirements in Table 9.5.1 cannot be satisfied, direct calculations carried out in accordance with 5.3 may be considered.

5.1.8 The connection between the strut and the pod body should generally be effected through large radiused fillets in cast pod units or curved plates in fabricated pod units.

5.1.9 The structural response under the most onerous combination of loads is not to exceed the normal operational requirements of the propulsion or steering system components.

5.1.10 For cast pod structures, the elongation of the material on a gauge length of 5,65 $\sqrt{S_o}$ is to be not less than 12 per cent where S_o is the actual cross sectional area of the test piece.

5.1.11 In castings, sudden changes of section or possible constriction to the flow of metal during casting are to be avoided. All fillets are to have adequate radii, which should, in general, be not less than 75 mm.

5.1.12 Castings are to comply with the requirements of Chapters 4 or 7 of the Rules for Materials.

5.2 Hull support structure

5.2.1 For supporting the main slewing bearing outer races, a system of primary structural members is to be provided in order to transfer the maximum design loads and moments from the podded propulsion unit into the unit's hull without undue deflection. Due account is also to be taken of the loads induced by the maximum unit's motions in the vertical direction resulting from combined heave and pitch motion of the unit. Account is also to be taken of any manoeuvring conditions that are likely to give rise to high mean or vibratory loadings induced by the podded propulsion unit. *See* 2.2.1(c).

5.2.2 The hull support structure in way of the slewing bearing should be sufficiently stiff that the bearing manufacturer's limits on seating flatness are not exceeded due to hull flexure as a consequence of the loads defined under 5.2.1.

Table 9.5.1 Podded propulsion unit – fabricated structure requirements

Location	Requirement	Notes
Strut external shell plating	Thickness, in mm, is to be not less than: $t = 0{,}0063 s\, f\, (h_7\, k)^{0,5}$	The minimum thickness of plating diaphragms and primary webs within the strut is to be not to less than the Rule requirement for the strut external plating. For internal diaphragms, panel stiffening is to be provided where the ratio of spacing to plate thickness (*s*/*t*) exceeds 100. Where there are no secondary members, *s* is to be replaced by *S*.
Strut primary framing	The section modulus in cm^3 is to be not less than: $z = 7{,}75 h_7\, l_e^2\, S\, k$	This does not apply to full breadth plate diaphragms.
Strut secondary stiffening	The section in cm^3 is to be not less than: $z = 0{,}0056 h_7\, l_e^2\, s\, k$	This does not apply to full breadth plate diaphragms.
Cylindrical pod body external shell plating	Thickness, in mm, is to be not less than: $t = 3{,}0 R_g\, (h_7\, k)^{0,5}$	Not to be less than the Rule basic shell end thickness from Table 3.2.1 in Pt 3, Ch 3,2 of the Rules for Ships.
Symbols		
f = panel aspect ratio correction factor = $[1{,}1 - s/(2500S)]$ h_7 = $(T + C_w + 0{,}014V^2)$ k = local higher tensile steel factor, as in Pt 3, Ch 2 of the Rules for Ships l_e = effective span of the member under consideration, in metres s = the frame spacing of secondary members, in mm C_w = design wave amplitude, in metres, as in Pt 4, Ch 1,1.5 of the Rules for Ships R_g = mean radius of pod body tube, in metres S = the spacing of primary members, in metres T = the vessel scantling draft, in metres, as in Pt 3, Ch 1,6.1 of the Rules for Ships V = ship service speed, in knots, as in Pt 3, Ch 1,6.1 of the Rules for Ships		

5.2.3 Generally, the system of primary members is to comprise a pedestal girder directly supporting the slewing ring and bearing. The pedestal girder is to be integrated with the unit's structure by means of radial girders and transverses aligned at their outer ends with the unit's bottom girders and transverses, *see* Fig. 9.5.1. Proposals to use alternative arrangements that provide an equivalent degree of strength and rigidity may be submitted for appraisal.

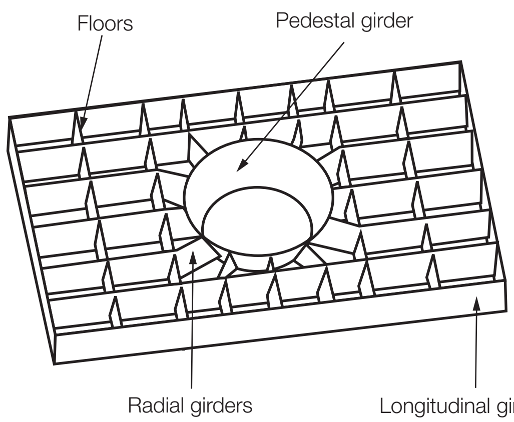


Fig. 9.5.1 Hull support structure

5.2.4 The unit's support structure in way of the podded unit may be of double or single bottom construction. Generally, podded drives should be supported where practical within a double bottom structure; however final acceptance of the supporting arrangements will be dependent upon satisfying the stress criteria set out in Table 9.5.2, *see also* 5.3.5.

5.2.5 The shell envelope plating and tank top plating in way of the aperture for the podded drive (i.e., over the extent of the radial girders shown in Fig. 9.5.1) are to be increased by 50 per cent over the Rule minimum thickness to provide additional local stiffness and robustness. However the thickness of this plating is not to be less than the actual fitted thickness of the surrounding shell or tank top plating.

5.2.6 The scantlings of the primary support structure in way of the podded drive are to be based upon the limiting design stress criteria specified in Table 9.5.2, *see also* 5.3.5. Primary member scantlings are, however, not to be less than those required by Pt 3, Ch 6,5 of the Rules for Ships.

5.2.7 The pedestal girder is to have a thickness not less than the required shell envelope minimum Rule thickness in way. Where abutting plates are of dissimilar thickness then the taper requirements of Pt 3, Ch 10,2 of the Rules for Ships are to be complied with.

5.2.8 In general, full penetration welds are to be applied at the pedestal girder boundaries and in way of the end connections between the radial girders and the pedestal girder. Elsewhere, for primary members, double continuous fillet welding is to be applied using a minimum weld factor of 0,34.

5.3 Direct calculations

5.3.1 Finite element or other direct calculation techniques may be employed in the verification of the structural design. The mesh density used, is to be sufficient to accurately demonstrate the response characteristics of the structure and to provide adequate stress and deflection information. A refined mesh density is to be applied to geometry transition areas and those locations where high localised stress or stress gradients are anticipated.

5.3.2 Model boundary constraints are generally to be applied in way of the slewing ring/unit attachment only.

Table 9.5.2 Direct calculation maximum permissible stresses for steel fabricated structures

Permissible stress values		
Location	Podded drive structure	Podded drive/hull interface
X-Y shear stress	0,26σ_o	0,35σ_o
Direct stress due to bending	0,33σ_o	0,63σ_o
Von Mises stress	0,40σ_o	0,75σ_o
Localised Von Mises peak stresses	σ_o	σ_o
Symbols		
σ_o = minimum yield strength of the material		

NOTES
1. The values stated above are intended to give an indication of the levels of stress in the pod and ship structure for the maximum loads which could be experienced during normal service.
2. If design is based on extreme or statistically low probability loads, then proposals to use alternative acceptance stress criteria may be considered.

5.3.3 The loads applied to the mathematical model, *see* 2.4.1, are to include the self weight, dynamic acceleration due to unit motion, hydrodynamic loads, hydrostatic pressure, propeller forces and shaft bearing support forces. In situations where a pod can operate in the flooded conditions, or where flooding of a pod adds significant mass to the pod, details are to be included.

5.3.4 Based on the most onerous combination of normal service loading conditions, the stress criteria shown in Table 9.5.2 are not to be exceeded. *See also* 2.2.1(c).

5.3.5 Where the structural design is based on a fatigue assessment and the stress criteria shown in Table 9.5.2 are not applicable, details of cumulative load history and stress range together with the proposed acceptance criteria are to be submitted for consideration.

5.3.6 For cast structures, the localised von Mises stress should not exceed 0,6 times the nominal 0,2 per cent proof or yield stress of the material for the most onerous design condition.

■ *Section 6*
Machinery design and construction requirements

6.1 General

6.1.1 The requirements detailed in Chapter 1 are applicable.

6.1.2 Means are to be provided whereby normal operation of the podded propulsion system can be sustained or readily restored if one of the supporting auxiliaries becomes inoperative. *See also* 2.1.1. Consideration shall be given to the malfunctioning of:

- sources of lubricating oil pressure,
- sources of cooling,
- hydraulic, pneumatic or electrical means for control of the podded propulsor.

6.2 Gearing

6.2.1 If gearing is used in the propulsion system, then the requirements of Chapter 5 are applicable.

6.3 Propulsion shafting

6.3.1 In addition to meeting the requirements of Chapters 6 and 8, the pod propulsion shafting supporting an electric motor is to be sufficiently stiff that both static and dynamic shaft flexure are within the motor manufacturer's limits for all envisaged operating conditions.

6.3.2 There is to be no significant lateral vibration response that may cause damage to the shaft seals within ±20 per cent of the running speed range. For vibration analysis computations, the influence of the slewing ring and shaft bearing stiffnesses, together with the contribution from the seating stiffnesses are to be included in the calculation procedures.

6.3.3 As an alternative to the requirements of Chapter 6, a fatigue strength analysis of shafting components indicating a factor of safety of 1,5 at the design loads based on a suitable fatigue failure criterion may be submitted for consideration. The effects of stress concentrations, material properties and operating environment are to be taken into account.

6.3.4 With the exception of the propeller connection (requirements stated in Chapter 7) couplings relying on friction are to have a factor of safety of 2,5 against slippage at the maximum rated torque. In order to reduce the possibility of fretting, a grip stress of not less than 20 N/mm^2 is to be attained.

6.3.5 The effects of motor short-circuit torque on the shafting system should not prevent continued operation once the fault has been rectified.

6.3.6 The arrangement of shaft bearings is to take account of shaft thermal expansion, misalignment of bearings, shaft slope through the bearings and manufacturing tolerances. Additionally, the influence of the pod deflection on the shaft bearing alignment is to be considered under the most onerous mechanical and hydrodynamic loading conditions.

6.3.7 Propeller shaft roller bearing life calculations are to take account of the following loadings:

- Shaft, motor, propeller and other shaft appendages' weights;
- Forces due to unit's motion;
- The propeller-generated forces and moments about the three Cartesian axes related to the shaft; f_x, f_y, f_z, m_x, m_y, m_z, *see* Fig. 9.2.1.
- Variance of propeller-generated forces and moments with pod azimuth angle. This load variance should take account of the motor control characteristics;
- Forces due to pod rotation, including gyroscopic forces;
- A predicted azimuth service profile for the pod indicating the proportion of time spent at various azimuth angles;
- Loads due to hydrodynamic interaction between pods;
- Any additional loads experienced during operation in ice conditions (for Ice Class notations);
- Where validation of the above loadings is available, detailed calculations must demonstrate that the bearing life when operating at the normal duty profile will comfortably exceed the time between 5-yearly surveys. Parameters used to justify the bearing life, i.e., those related to oil cleanliness, viscosity limits and material quality are to be quoted.

6.3.8 Where detailed validation of the loadings identified in 6.3.7. is not available, the calculations for roller bearings are to indicate a bearing life greater than 65,000 hours at the maximum continuous rating of the podded drive taking into account the azimuth angle duty cycle. Any parameters used to justify this life, i.e. those related to oil cleanliness, water contamination and viscosity limits are to be quoted. Proposals for the use of a shaft bearing of life less than 65,000 hours will be considered on application with details of alleviating factors and supporting documentation; however, this bearing life must exceed the time between surveys.

6.3.9 The design of the shaft line bearings is to take account of the maximum and minimum operating temperatures likely to be encountered during both a voyage cycle and, more widely, during the unit's operational life. Furthermore, any anticipated temperature distributions through the bearing components and structures are to be included in the design calculations.

6.3.10 Means are to be provided for detecting shaft bearing deterioration. Where rolling element shaft bearings are used in single pod applications or in pods where the motor power exceeds 6 MW, vibration monitoring of the shaft bearings is to be provided. The bearing monitoring system is to be suitable for the local bearing conditions and is to be able to differentiate from other vibration sources such as propeller cavitation or unit motions.

6.3.11 In multi-podded propulsor systems or units having at least one pod in association with other propulsion devices and where the individual pod installed power is greater than 5 MW, means are to be provided to hold the propeller for an inoperable unit stationary whilst the other pod(s) propel the vessel at a manoeuvring speed of not less than 7 knots. Operating instructions displayed at the holding mechanism's operating position are to include a direction to inform the bridge of any limitation in unit's speed required as a result of the holding mechanism being activated.

6.3.12 Shaft seals for maintaining the watertight integrity of the pod are to be Type Approved to a standard acceptable to LR. The seals are to be designed to withstand the extremes of operation for which they are intended and this is to include extremes of temperature, vibration, pressure and shaft movement.

6.3.13 In single pod installations, the integrity of shaft seals is to be evaluated on the basis of a double failure. In such installations, seal duplication is to be used with indication of failure of one seal being provided.

6.4 Propeller

6.4.1 The requirements of Chapter 7 are to be complied with.

6.4.2 Where propeller scantlings have been determined by a detailed fatigue analysis, based on reliable wake survey data as described in Ch 7,3.1.7, a factor of safety of 1,5 against suitable fatigue failure criteria is to be demonstrated. The effects of fillet stress concentrations, residual stress, fluctuating loads and material properties are to be taken into account.

6.5 Bearing lubrication system

6.5.1 The bearing lubrication system is to be arranged to provide a sufficient quantity of lubricant of a quality, viscosity and temperature acceptable to the bearing manufacturer under all unit operating conditions.

6.5.2 In addition to the requirements detailed in this Section, the requirements of Chapter 14, sub-Sections 8.1, 8.5, 8.7 and 8.9 are to be complied with.

6.5.3 For systems employing forced lubrication, the sampling points required by Ch 14,8.9.6 are to be located such that the sample taken is representative of the oil present at the bearing.

6.5.4 For lubricating oil systems employing gravity feed, the arrangements are to be such as to permit oil sampling and oil changes in accordance with the manufacturer's instructions for the safe and reliable operation of the propulsion system.

6.5.5 Where continuous operation of the lubricating oil system is essential for the pod to operate at its maximum continuous rating, a standby pump in accordance with Ch 14,8.2.2 is to be provided. In such systems, provision is to be made for the efficient filtration of the oil. The filters are to be capable of being cleaned without stopping the pod.

6.5.6 Where bearings are grease lubricated, means are to be provided for collecting waste grease to enable analysis for particulates and water. The arrangements for collecting waste grease are to be in accordance with the pod manufacturer's recommendations. Alternative arrangements which demonstrate that bearings are satisfactorily lubricated will be considered.

6.5.7 Pipework conveying lubricating oil is to be sited such that any possible leakage from joints will not impinge on electrical equipment, hot surfaces or other sources of ignition, *see also* Ch 13,2.9.3.

6.5.8 The procedures for flushing the lubrication system are to be defined. This procedure is to embrace the following conditions:

(a) Initial installation.
(b) Post maintenance situations.
(c) Major dry-docking refits.

See Section 10.

6.6 Steering system

6.6.1 The requirements of Chapter 19, Sections 1, 2, 3, 6, 7 and 8 are to be complied with where applicable. *See also* 3.1.

6.6.2 For vessels where a single podded propulsion unit is the sole means of propulsion, the requirement for auxiliary steering gear in Ch 19,2 is to be achieved by means of two or more identical power units.

6.6.3 Steering arrangements, other than of the hydraulic type, may be accepted provided that there are means of limiting the maximum torque to which the steering arrangement may be subjected.

6.6.4 The steering mechanism is to be provided with power that is sufficient for the maximum steering torques present during the declared functional capability identified in 3.1 and is to be demonstrated for the most onerous specified manoeuvring trial, *see* Section 9.

6.6.5 Geared arrangements employed for steering are to consider the following conditions:

- A design maximum dynamic duty steering torque, M_Z, *see* 2.4.1;
- A static duty (≤103 load cycles) steering torque. The static duty steering torque should not be less than M_W, the maximum torque which can be generated by the steering gear mechanism.

The minimum factors of safety, as derived using ISO 6336 Calculation of load capacity of spur and helical gears, or a recognised National Standard, are to be 1.5 on bending stress and 1,0 on Hertzian contact stress. The use of a duty factor in the dynamic duty strength calculations is acceptable but the derivation of such a factor, based on percentage of time spent at a percentage of the maximum working torque, should be submitted to LR for consideration and acceptance.

6.6.6 Slewing ring bearing capacity calculations are to take account of:

- Pod weight in water;
- Gyroscopic forces from the propeller and motor;
- Hydrodynamic loads on pod; and
- Forces due to unit's motions.

The calculations are to demonstrate that the factor of safety against the maximum combination of the above forces is not less than 2. The calculations are to be carried out in accordance with a suitable declared standard.

6.6.7 Means of allowing the condition of the slewing gears and bearings to be assessed are to be provided.

6.6.8 On multi podded units, means are to be provided to secure each pod unit's slewing mechanism in its mid position in the event of a steering system failure. These arrangements are to be of sufficient strength to hold the pod in position at the unit's manoeuvring speed to be taken as not less than 7 knots, *see also* 6.3.9. Operating instructions displayed at the securing mechanism's operating position are to include a direction to inform the bridge of any limitation in unit's speed required as a result of the securing mechanism being activated.

6.7 Ventilation and cooling systems

6.7.1 Means are to be provided to ensure that air used for motor cooling purposes is of a suitable temperature and humidity as well as being free from harmful particles.

6.7.2 Cooling water supplies are to comply with Ch 14,7. *See also* Pt 6, Ch 2,9.6 of the Rules for Ships.

6.7.3 On single podded installations, a standby cooling arrangement of the same capacity as the main cooling system, is to be provided and available for immediate use.

6.7.4 For pods having an electric propulsion motor but no active cooling system, heat balance calculations as required by 2.2.1(w) are to demonstrate that the pod unit and associated systems are able to function satisfactorily over all operating conditions, *see* Ch 1,3.5.

6.8 Pod drainage requirements

6.8.1 Unless the electrical installation is suitable for operation in a flooded space, means are to be provided to ensure that leakage from shaft bearings or the propeller seal do not reach the motor windings, or other electrical components. Account is to be taken of cooling air flow circulating within the pod unit.

6.8.2 Where the design of a pod space has a requirement to be maintained in a dry condition, two independent means of drainage are to be provided so that liquid leakage may be removed from the pod unit at all design angles of heel and trim, *see* Ch 1,3.6.

6.8.3 Pipework conveying leakage from the pod is to be sited such that any leakage from joints will not impinge on electrical equipment, *see also* Ch 13,2.9.3.

6.9 Hydraulic actuating systems

6.9.1 Hydraulic actuating systems are to comply with Ch 14,9 and Ch 19,3 as applicable.

■ *Section 7* Electrical equipment

7.1 General

7.1.1 The electrical installation is to be designed, constructed and installed in accordance with the requirements of Pt 6, Ch 2.

7.1.2 Means are to be provided to prevent electrical currents flowing across shaft bearings, which may cause their premature failure.

7.1.3 Steering gear electrical systems are to comply with Ch 19,5.

7.2 Slip rings

7.2.1 Where slip rings are incorporated in the design, the details of the following are to be submitted for consideration:

(a) temperature rise test reports;
(b) maximum permitted temperature ratings and design operating temperatures for materials;
(c) where applicable, arrangements for forced air or liquid-cooling;
(d) for data communication link slip rings, evidence to demonstrate compliance with Pt 6, Ch 1,2.11.3 of the Rules for Ships.

(e) suitability for use under the conditions of vibration expected to arise in normal operation;
(f) evidence of satisfactory operation under the normal angles of inclination given in Pt 6, Ch 2,1.10;
(g) cable securing arrangements; and
(h) evidence of electromagnetic compatibility of control, alarm and safety systems with power circuits.

7.2.2 Where forced cooling is used on slip rings, an alarm is to be initiated to indicate the failure of the forced cooling and it is to be possible to operate the slip ring at a reduced power level defined by the Manufacturer in the event of failure of the forced cooling.

■ *Section 8* Control engineering arrangements

8.1 General

8.1.1 Control engineering arrangements are to be in accordance with Pt 6, Ch 1.

8.1.2 Steering gear control, monitoring and alarm systems are to comply with Ch 19,4 and Ch 19,5.

8.1.3 Steering control is to be provided for podded drives from the navigating bridge and locally.

8.1.4 An indication of the angular position of the podded propulsion unit(s) and the magnitude of the thrust is to be provided at each station from which it is possible to control the direction of thrust. This indication is to be independent of the steering control system.

8.1.5 Means are to be provided at the remote control station(s), independent of the podded drive control system, to stop each podded drive in an emergency. *See also* Pt 6, Ch 2,16.4.7 of the Rules for Ships.

8.1.6 Where programmable electronic equipment is used to prevent loads exceeding those for which the system has been designed (*see* 2.4.3), then either:
(a) A fully independent hard wired backup is to be provided; or
(b) The software is to be certified in accordance with LR's Software Conformity Assessment System – Assessment Module GEN1 (1994) and have an independent solution showing redundancy with design diversity, etc., *see* Pt 6, Ch 1,2.13 of the Rules for Ships.

8.1.7 Where a propulsion system which includes a podded propulsor unit is controlled by a series of interactive and integrated programmable electronic systems, then these are to comply with the requirements of Pt 6, Ch 1,2.13 of the Rules for Ships.

8.1.8 For electronic control systems and electrical actuating systems, an overall quality plan for sourcing, design, installation and testing is to address the following issues:
(a) Standard(s) applied.
(b) Details of the quality control system applied during manufacture and testing.
(c) Details of type approval, type testing or approved type status assigned to the equipment.
(d) Details of installation and testing recommendations for the equipment.
(e) Details of any local and/or remote diagnostic arrangements where assessment and alteration of control parameters can be made which can affect the operation of the podded propulsor unit.
(f) Software lifecycle activities, including configuration management and arrangements for software upgrades.

8.1.9 The quality plan referred to in 8.1.8 to identify the process for verification of the functional outputs from the electronic control systems with particular reference to system integrity, consistency, security against unauthorised changes to software and maintaining the outputs within acceptable tolerances of stated performance for safe and reliable operation of the podded propulsor unit.

8.1.10 For the permitted range of operating conditions, the control system is to be capable of protecting the podded propulsor from experiencing mechanical loads that may initiate damage while permitting the desired manoeuvres to take place.

8.2 Monitoring and alarms

8.2.1 The requirements for alarms and monitoring arrangements are to be in accordance with Ch 19,5.3 and Table 9.8.1. These alarms are in addition to the requirements of Pt 6, Ch 2,16.

8.2.2 Alarms specified in Table 9.8.1 are to be in accordance with the alarm system specified by Pt 6, Ch 1,2,3.

8.2.3 Sensors for control, monitoring and alarm systems required by the Rules and located within the pod are to be duplicated in order that a single sensor failure does not inhibit system functionality.

8.2.4 Pod unit dry space pumping arrangements are to function automatically in the event of a high liquid level being detected in the pod unit.

8.2.5 Spaces intended to be dry are to be provided with arrangements to indicate water ingress in accordance with 8.2.6 and Table 9.8.1.

8.2.6 The number and location of dry space level detectors are to be such that accumulation of liquids will be detected at all design angles of heel and trim.

8.2.7 Condition monitoring arrangements are not to interface with the operation of safety systems which may cause slow-down or shut-down of the propulsion system. *See also* Pt 6, Ch 1,2.6.9 of the Rules for Ships.

8.2.8 Means are to be provided to identify the cause of propulsion motor power limitation or automatic reduction.

Table 9.8.1 Additional alarms and safeguards for podded propulsion units

Item	Alarm	Note
Podded drive azimuth angle	—	Indicator, *see* 8.1.4
Propulsion motors	Power supply failure	To be indicated on the navigating bridge
Propulsion motor power limitation or automatic reduction	Activated	*See also* Pt 6, Ch 2,16.4.9 of the Rules for Ships
Hydraulic oil system pressure	Low	To be indicated on the navigating bridge
Bearing temperature	High	For grease lubricated bearings
Motor temperature	High	*See* Pt 6, Ch 2, 16.1.3 of the Rules for Ships
Lubricating oil supply pressure	Low	If separate forced lubrication for shaft bearings; to be indicated on the navigating bridge
Lubricating oil temperature	High	*See also* Pt 6, Ch 2,16.5.11 of the Rules for Ships
Lubricating oil tank level for motor bearings	Low	
Water in lubricating oil for motor bearings	High	Required for single podded propulsion units only
Motor cooling air inlet temperature	High	
Motor cooling air outlet temperature	High	
Motor cooling air flow	Low	
Shaft bearing vibration monitoring	High	*See* 6.3.10. Monitoring is to allow bearing condition to be gauged using trend analysis
Shaft sealing	Failure	*See* 6.3.13
Dry space water pump operation	Abnormal	Alarm set to indicate a frequency or duration exceeding that which would normally be expected
Dry space water level	1st stage high 2nd stage high	— Propulsion motor is to shut down automatically, *See* Note
Slip ring forced cooling	Failure	*See* 7.2.2

NOTE
The second stage dry space water level high alarm is not needed where the electrical equipment installed within the pod is suitable for operation in flooded spaces, *see* 6.8.1.

■ *Section 9* Testing and trials

9.1 General

9.1.1 The following requirements are to be complied with:

- Ch 1,5.2 for sea trials.
- Ch 19,7.2 for steering trials.

In addition, the functional capability specified in 3.1.1 is to be demonstrated to the Surveyor's satisfaction.

9.1.2 The actual values of steering torque are to be verified during sea trials to confirm that the design maximum dynamic duty torque has not been exceeded.

9.1.3 Electric motor cooling systems are to be verified, as far as possible, to ensure that they are capable of limiting the extremes of ambient temperature to those specified in 2.3.1.

9.1.4 Any trials and testing identified from the FMEA report, *see* 2.5.4(f), are also to be carried out.

■ *Section 10* Installation, maintenance and replacement procedures

10.1 General

10.1.1 All podded propulsion units are to be supplied with a copy of the manufacturer's installation and maintenance manual that is pertinent to the actual equipment.

10.1.2 The manual required by 10.1.1 is to be placed on board and is to contain the following information:

(a) Description of the podded propulsion unit with details of function and design operating limits. This is also to include details of support systems such as lubrication, cooling and condition monitoring arrangements.
(b) Identification of all components together with details of any that have a defined maximum operating life.
(c) Instructions for installation of unit(s) on board unit with details of any required specialised equipment.
(d) Instructions for commissioning at initial installation and following maintenance.

(e) Maintenance and service instructions to include inspection/renewal of bearings, seals, motors, slip rings and other major components. This is also to include component fitting procedures, special environmental arrangements, clearance and push-up measurements and lubricating oil treatment where applicable.

(f) Actions required in the event of fault/failure conditions being detected.

(g) Precautions to be taken by personnel working during installation and maintenance.

Section

■ *Section 1* General requirements

1.1 Application

1.1.1 The requirements of this Chapter are applicable to fusion welded pressure vessels and their mountings and fittings, for the following uses:

(a) Production or storage of steam.
(b) Heating of pressurised hot water above 120°C.
(c) Heating of pressurised thermal liquid.

The formulae in this Chapter may be used for determining the thickness of seamless pressure vessels using a joint factor of 1,0. Seamless pressure vessels are to be manufactured and tested in accordance with the requirements of Chapter 5 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

1.1.2 The scantlings of coil type heaters with pumped circulation, which are fired or heated by exhaust gas, are to comply with the appropriate requirements of this Chapter.

1.1.3 Fired and unfired pressure vessels associated with process plant and drilling plant are to comply with the requirements of Pt 3, Ch 8,4 of these Rules.

1.2 Definition of symbols

1.2.1 The symbols used in the various formulae in Sections 2 to 8, unless otherwise stated, are defined as follows and are applicable to the specific part of the pressure vessel under consideration:

d = diameter of hole or opening, in mm
p = design pressure, *see* 1.3, in bar
r_i = inside knuckle radius, in mm
r_o = outside knuckle radius, in mm
s = pitch, in mm
t = minimum thickness, in mm
D_i = inside diameter, in mm
D_o = outside diameter, in mm
J = joint factor applicable to welded seams, *see* 1.9, or ligament efficiency between tube holes (expressed as a fraction, *see* 2.2)
R_i = inside radius, in mm
R_o = outside radius, in mm
T = design temperature, in °C
σ = allowable stress, *see* 1.8, in N/mm^2.

1.2.2 Where reference is made to calculated or actual plate thickness for the derivation of other values, these thicknesses are to be minus the standard Rule corrosion allowance of 0,75 mm, if not so stated.

1.3 Design pressure

1.3.1 The design pressure is the maximum permissible working pressure and is to be not less than the highest set pressure of any safety valve.

1.3.2 The calculations made to determine the scantlings of the pressure parts are to be based on the design pressure, adjusted where necessary to take account of pressure variations corresponding to the most severe operational conditions.

1.3.3 It is desirable that there should be a margin between the normal pressure at which the boiler or pressure vessel operates and the lowest pressure at which any safety valve is set to lift, to prevent unnecessary lifting of the safety valve.

1.4 Metal temperature

1.4.1 The metal temperature, T, used to evaluate the allowable stress, σ, is to be taken as the actual mean wall metal temperature expected under operating conditions for the pressure part concerned, and is to be stated by the manufacturer when plans of the pressure parts are submitted for consideration.

1.4.2 The following values are to be regarded as the minimum:

(a) For fired steam boilers, *T* is to be taken as not less than 250°C.
(b) For steam heated generators, secondary drums of double evaporation boilers, steam receivers and pressure parts of fired pressure vessels, not heated by hot gases and adequately protected by insulation, *T* is to be taken as the maximum temperature of the internal fluid.
(c) For pressure parts heated by hot gases, *T* is to be taken as not less than 25°C in excess of the maximum temperature of the internal fluid.
(d) For boiler, superheater, reheater and economiser tubes, *T* is to be taken as indicated in 7.1.2.
(e) For combustion chambers of the type used in horizontal wet-back boilers, *T* is to be taken as not less than 50°C in excess of the maximum temperature of the internal fluid.
(f) For furnaces, fireboxes, rear tube plates of dry-back boilers and pressure parts subject to similar rates of heat transfer, *T* is to be taken as not less than 90°C in excess of the maximum temperature of the internal fluid.

1.4.3 In general, any parts of boiler drums or headers not protected by tubes, and exposed to radiation from the fire or to the impact of hot gases, are to be protected by a shield of good refractory material or by other approved means.

1.4.4 Drums and headers of thickness greater than 35 mm are not to be exposed to combustion gases having an anticipated temperature in excess of 650°C unless they are efficiently cooled by closely arranged tubes.

1.5 Classification of fusion welded pressure vessels

1.5.1 For Rule purposes, pressure vessels with fusion welded seams are graded as Class 1 if they comply with the following conditions:

(a) For pressure parts of fired steam boilers, fired thermal liquid heaters and exhaust gas heated shell type steam boilers where the design pressure exceeds 3,4 bar.
(b) For pressure parts of steam heated steam generators and separate steam receivers where the design pressure exceeds 11,3 bar, or where the pressure, in bar, multiplied by the internal diameter of the shell, in mm, exceeds 14 420.

1.5.2 For Rule purposes, pressure vessels with fusion welded seams used for the production or storage of steam, the heating of pressurised hot water above 120°C or the heating of pressurised thermal liquid not included in Class 1 are graded as Class 2/1 and 2/2.

1.5.3 Pressure vessels which are constructed in accordance with Class 2/1 or Class 2/2 Standards (as indicated above) will, if manufactured in accordance with requirements of a superior class, be approved with the scantlings appropriate to that class.

1.5.4 Pressure vessels which have only circumferential fusion welded seams will be considered as seamless with no class being assigned. Preliminary weld procedure tests and non-destructive examination for the circumferential seam welds should be carried out for the equivalent class as determined by 1.5.1 and 1.5.2.

1.5.5 In special circumstances relating to service conditions, materials, operating temperature, the carriage of dangerous gases and liquids, etc., it may be required that certain pressure vessels be manufactured in accordance with the requirements of a superior class.

1.5.6 Details of heat treatment, non-destructive examination and routine tests (where required) are given in Chapter 13 of the Rules for Materials.

1.5.7 Hydraulic testing is required for pressure vessels of Class 1, 2/1 and 2/2.

1.6 Plans

1.6.1 Plans of boilers, superheaters and economisers are to be submitted in triplicate for consideration. When plans of water tube boilers are submitted for approval, particulars of the safety valves and their disposition on boilers and superheaters, together with the estimated pressure drop through the superheaters, are to be stated. The pressures proposed for the settings of boiler and superheater safety valves are to be indicated on the boiler plan.

1.6.2 Plans, in triplicate, showing full constructional features of fusion welded pressure vessels and dimensional details of the weld preparation for longitudinal and circumferential seams and attachments, together with particulars of the welding consumables and of the mechanical properties of the materials, are to be submitted before construction is commenced.

1.6.3 Plans, in triplicate, showing details of the air flow through the combustion chamber, boiler furnace and boiler uptake spaces, including measures taken to assure effective purging in all of the spaces, are to be submitted for consideration.

1.6.4 Plans, in triplicate, showing all areas of refractory material in the combustion chamber and boiler furnace spaces, are to be submitted for consideration. *See* 1.12.1.

1.6.5 Calculations, in triplicate, showing that a minimum of 4 air changes of the combustion chamber, boiler furnace and boiler uptake spaces will be achieved during automatic purging operations, with details of the forced draft fans and arrangements of air flow from fan intake to flue outlet, are to be submitted for consideration, *see* 1.12.1.

1.6.6 Calculations, in triplicate, are to be submitted showing that the ventilation of machinery spaces containing boilers is adequate for the air consumers within the space with an unimpaired air supply, in accordance with the equipment manufacturer's recommendations, under operating conditions as defined in Ch 1,4.4.2.

1.7 Materials

1.7.1 Materials used in the construction are to be manufactured and tested in accordance with the requirements of the Rules for Materials.

1.7.2 The specified minimum tensile strength of carbon and carbon-manganese steel plates, pipes, forgings and castings is to be within the following general limits:

(a) For seamless, Class 1, Class 2/1 and Class 2/2 fusion welded pressure vessels:
340 to 520 N/mm^2.

(b) For boiler furnaces, combustion chambers and flanged plates:
400 to 520 N/mm^2.

1.7.3 The specified minimum tensile strength of low alloy steel plates, pipes, forgings and castings is to be within the general limits of 400 to 500 N/mm^2 and pressure vessels made in these steels are to be either seamless or Class 1 fusion welded.

1.7.4 The specified minimum tensile strength of boiler and superheater tubes is to be within the following general limits:

(a) Carbon and carbon-manganese steels:
320 to 460 N/mm^2.

(b) Low alloy steels:
400 to 500 N/mm^2.

1.7.5 Where it is proposed to use materials other than those specified in the Rules for Materials, details of the chemical compositions, heat treatment and mechanical properties are to be submitted for approval. In such cases the values of the mechanical properties used for deriving the allowable stress are to be subject to agreement by Lloyd's Register (hereinafter referred to as 'LR').

1.7.6 Where a fusion welded pressure vessel is to be made of alloy steel, and approval of the scantlings is required on the basis of the high temperature properties of the material, particulars of the welding consumables to be used, including typical mechanical properties and chemical composition of the deposited weld metal, are to be submitted for approval.

1.8 Allowable stress

1.8.1 The term 'allowable stress', σ, is the stress to be used in the formulae for the calculation of scantlings of pressure parts.

1.8.2 The allowable stress, σ, is to be the lowest of the following values:

$$\sigma = \frac{E_t}{1,5} \qquad \sigma = \frac{R_{20}}{2,7} \qquad \sigma = \frac{S_R}{1,5}$$

where

E_t = specified minimum lower yield stress or 0,2 per cent proof stress at temperature, T

R_{20} = specified minimum tensile strength at room temperature

S_R = average stress to produce rupture in 100 000 hours at temperature, T

T = metal temperature, *see* 1.4.

1.8.3 The allowable stress for steel castings is to be taken as 80 per cent of the value determined by the method indicated in 1.8.2, using the appropriate values for cast steel.

1.8.4 Where steel castings, which have been tested in accordance with the Rules for Materials, are also subjected to non-destructive tests, consideration will be given to increasing the allowable stress using a factor up to 90 per cent in lieu of the 80 per cent referred to in 1.8.3. Particulars of the non-destructive test proposals are to be submitted for consideration.

1.9 Joint factors

1.9.1 The following joint factors are to be used in the equations in Sections 2 to 8, where applicable. Fusion welded pressure parts are to be made in accordance with Chapter 17.

Class of pressure vessel	Joint factor
Class 1	1,0
Class 2/1	0,85
Class 2/2	0,75

1.9.2 The longitudinal and circumferential joints for all classes of pressure vessels for the purposes of this Chapter are to be butt joints. For typical acceptable methods of attaching dished ends, *see* Fig. 10.14.1.

1.10 Pressure parts of irregular shape

1.10.1 Where pressure parts are of such irregular shape that it is impracticable to design their scantlings by the application of formulae in Sections 2 to 8, the suitability of their construction is to be determined by hydraulic proof test of a prototype or by agreed alternative method.

1.11 Adverse working conditions

1.11.1 Where working conditions are adverse, special consideration may be required to be given to increasing the scantlings derived from the formulae. In this connection, where necessary, account should also be taken of any excess of loading resulting from:

(a) impact loads, including rapidly fluctuating pressures;
(b) weight of the vessel and normal contents under operating and test conditions;
(c) superimposed loads such as other pressure vessels, operating equipment, insulation, corrosion-resistant or erosion-resistant linings and piping;
(d) reactions of supporting lugs, rings, saddles or other types of supports; or
(e) the effect of temperature gradients on maximum stress.

1.12 Furnace explosion prevention

1.12.1 The design of combustion chamber and furnace arrangements is to incorporate measures to minimise the risk of explosion as far as practicable. Measures are to be taken to prevent the accumulation of flammable gases in spaces which may not effectively be reached by purging air. Measures are to be taken to minimise heat retaining surfaces, e.g., refractory which can become sources of ignition in the furnace and uptakes.

1.13 Exhaust gas economiser/boiler arrangements

1.13.1 The design of exhaust gas economisers/boilers of the plain or extended surface fin tube types is to be compatible with the installed engine design parameters. The parameters which influence the build up of soot deposits and overheating such as fuel, exhaust gas temperature and efflux velocity are to be considered in the design of the exhaust gas economiser/boiler for use with the installed engine, in order to minimise the risk of fire and breakdown during operation.

1.13.2 A design statement demonstrating compliance with the requirements of 1.13.1 or alternative means of preventing the accumulation of soot or overheating, such as the use of exhaust gas bypass ducting with automatic flap valve arrangements and/or effective soot prevention and cleaning systems, is to be submitted for approval.

■ *Section 2* Cylindrical shells and drums subject to internal pressure

2.1 Minimum thickness

2.1.1 Minimum thickness, t, of a cylindrical shell is to be determined by the following formula:

$$t = \frac{p R_i}{10\sigma J - 0{,}5p} + 0{,}75 \text{ mm}$$

where

t, p, R_i and σ are defined in 1.2,

J = efficiency of ligaments between tube holes or other openings in the shell or the joint factor of the longitudinal joints (expressed as a fraction). *See* 1.9 or 2.2, whichever applies. In the case of seamless shells clear of tube holes or other openings, J = 1,0.

2.1.2 The formula in 2.1.1 is applicable only where the resulting thickness does not exceed half the internal radius, i.e., where R_o is not greater than $1{,}5R_i$.

2.1.3 Irrespective of the thickness determined by the above formula, t is to be not less than:

(a) 6,0 mm for cylindrical shell plates.

(b) For tube plates, such thickness as will give a minimum parallel seat of 9,5 mm, or such greater width as may be necessary to ensure tube tightness, *see* 14.6.

2.2 Efficiency of ligaments between tube holes

2.2.1 Where tube holes are drilled in a cylindrical shell in a line or lines parallel to its axis, the efficiency, J, of the ligaments is to be determined as in 2.2.2, 2.2.3 and 2.2.4.

2.2.2 **Regular drilling**. Where the distance between adjacent tube holes is constant, *see* Fig. 10.2.1,

$$J = \frac{s - d}{s}$$

where

d = the mean effective diameter of the tube holes, in mm, after allowing for any serrations, counter-boring or recessing, or the compensating effect of the tube stub. *See* 2.3 and 2.4.

s = pitch of tube holes, in mm.

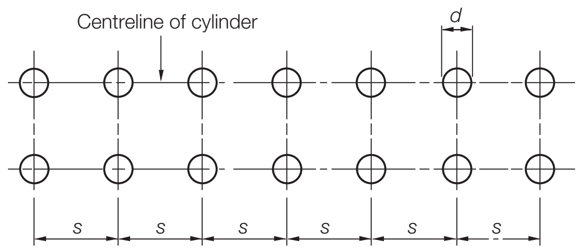


Fig. 10.2.1 Regular drilling

2.2.3 **Irregular drilling**. Where the distance between centres of adjacent tube holes is not constant, *see* Fig. 10.2.2:

$$J = \frac{s_1 + s_2 - 2d}{s_1 + s_2}$$

where d is as defined in 2.2.2

s_1 = the shorter of any two adjacent pitches, in mm

s_2 = the longer of any two adjacent pitches, in mm.

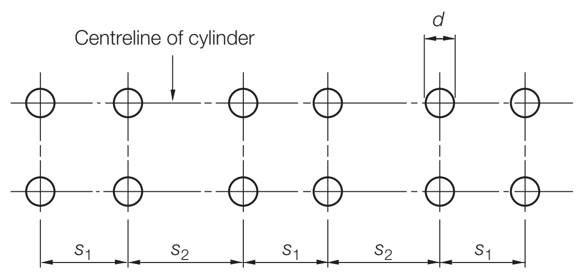


Fig. 10.2.2 Irregular drilling

2.2.4 When applying the formula in 2.2.3, the double pitch ($s_1 + s_2$) chosen is to be that which makes J a minimum, and in no case is s_2 to be taken as greater than twice s_1.

2.2.5 Where the circumferential pitch between tube holes measured on the mean of the external and internal drum or header diameters is such that the circumferential ligament efficiency determined by the formulae in 2.2.2 and 2.2.3 is less than one half of the ligament efficiency on the longitudinal axis, *J* in 2.1 is to be taken as twice the circumferential efficiency.

2.2.6 Where tube holes are drilled in a cylindrical shell along a diagonal line with respect to the longitudinal axis, the efficiency, *J*, of the ligaments is to be determined as in 2.2.7 to 2.2.10.

2.2.7 For spacing of tube holes on a diagonal line as shown in Fig. 10.2.3, or in a regular saw-tooth pattern as shown in Fig. 10.2.4, *J* is to be determined from the formula in 2.2.8, where *a* and *b*, as shown in Figs. 10.2.3 and 10.2.4, are measured, in mm, on the median line of the plate, and *d* is as defined in 2.2.2.

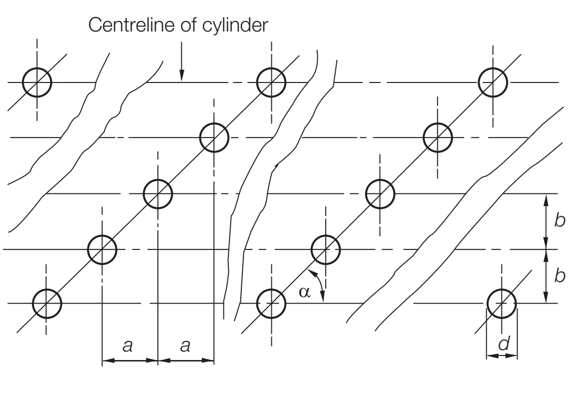


Fig. 10.2.3 Spacing of holes on a diagonal line

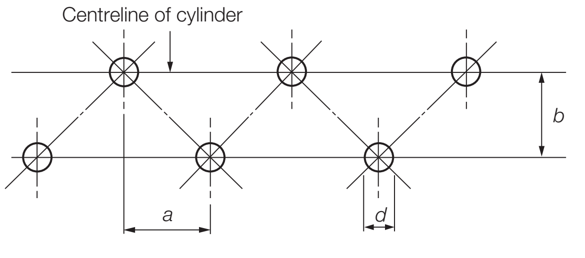


Fig. 10.2.4 Regular saw-tooth pattern of holes

2.2.8 For tube holes on a diagonal line:

$$J = \frac{2}{A + B + \sqrt{(A - B)^2 + 4C^2}}$$

where

$$A = \frac{\cos^2 \alpha + 1}{2\left(1 - \dfrac{d \cos \alpha}{a}\right)}$$

$$B = 0{,}5 \left(1 - \frac{d \cos \alpha}{a}\right) (\sin^2 \alpha + 1)$$

$$C = \frac{\sin \alpha \cos \alpha}{2\left(1 - \dfrac{d \cos \alpha}{a}\right)}$$

$$\cos \alpha = \frac{1}{\sqrt{1 + \dfrac{b^2}{a^2}}}$$

$$\sin \alpha = \frac{1}{\sqrt{1 + \dfrac{a^2}{b^2}}}$$

α = angle between centreline of cylinder and centreline of diagonal holes.

2.2.9 For regularly staggered spacing of tube holes as shown in Fig. 10.2.5, the smallest value of the efficiency, *J*, of all ligaments (longitudinal, circumferential and diagonal) is obtained from Fig. 10.2.6, where *a* and *b* as shown in Fig. 10.2.5 are measured, in mm, on the median line of the plate, and *d* is as defined in 2.2.2.

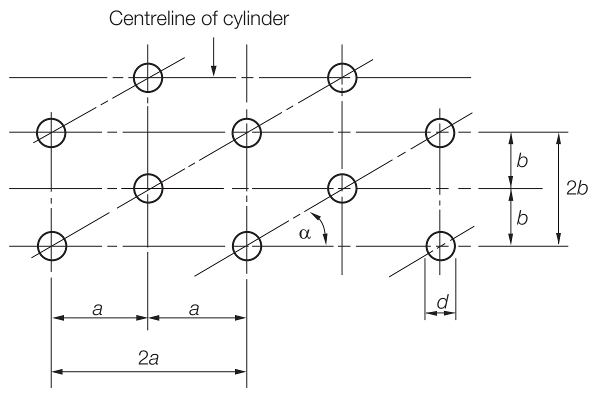


Fig. 10.2.5 Regular staggering of holes

2.2.10 For irregularly spaced tube holes whose centres do not lie on a straight line, the formula in 2.2.3 is to apply, except that an equivalent longitudinal width of the diagonal ligament is to be used. An equivalent longitudinal width is that width which gives, using the formula in 2.2.2, the same efficiency as would be obtained using the formula in 2.2.8 for the diagonal ligament in question.

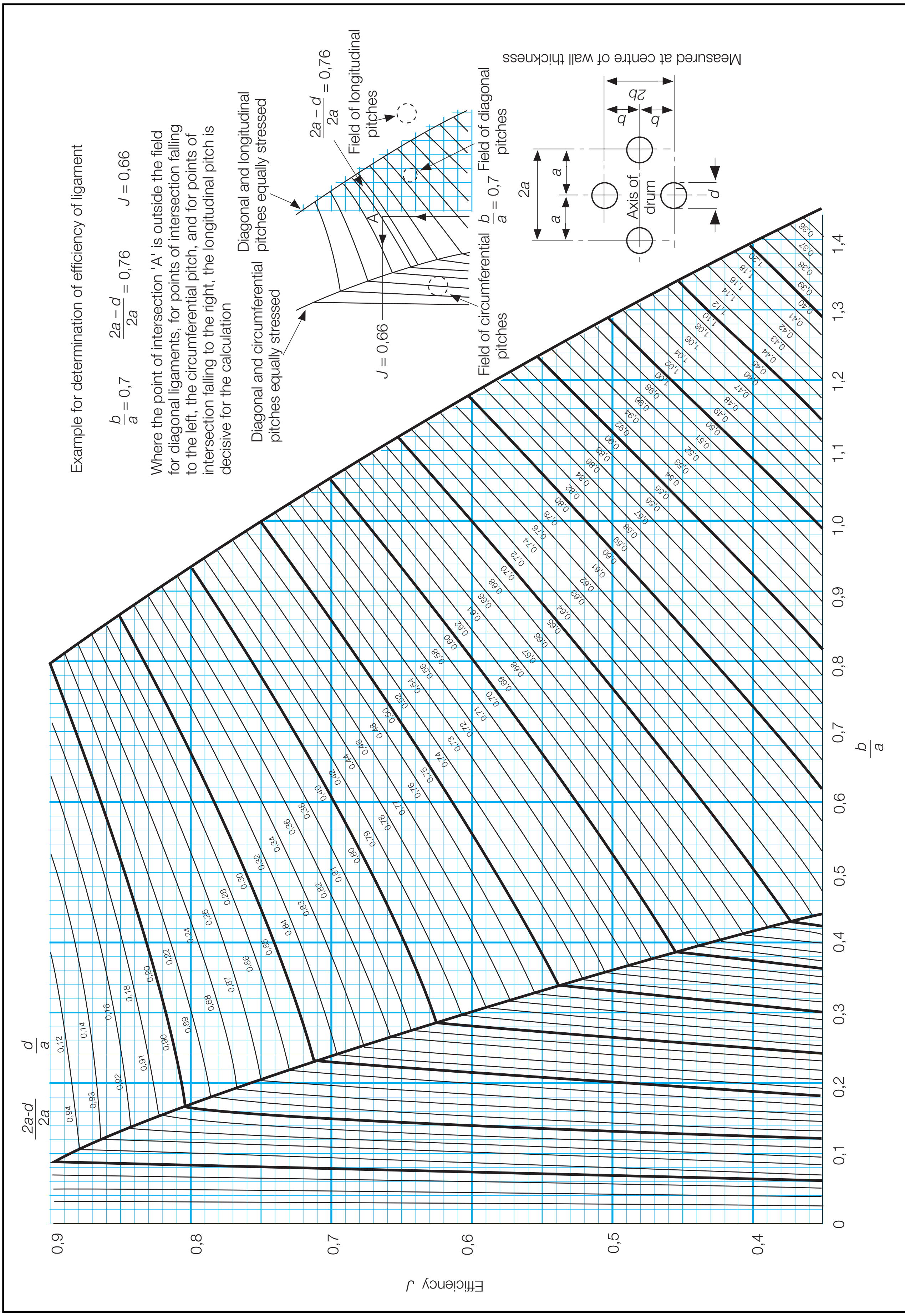


Fig. 10.2.6 Efficiency of ligaments between holes

2.3 Compensating effect of tube stubs

2.3.1 Where a drum or header is drilled for tube stubs fitted by strength welding, either in line or in staggered formation, the effective diameter of holes is to be taken as:

$$d_e = d_a - \frac{A}{t}$$

where

d_e = the equivalent diameter of the hole, in mm
d_a = the actual diameter of the hole, in mm
t = the thickness of the shell, in mm
A = the compensating area provided by each tube stub and its welding fillets, in mm^2.

2.3.2 The compensating area, A, is to be measured in a plane through the axis of the tube stub parallel to the longitudinal axis of the drum or header and is to be calculated as follows, *see* Figs. 10.2.7 and 10.2.8:

- The cross-sectional area of the stub, in excess of that required by 7.1 for the minimum tube thickness, from the interior surface of the shell up to a distance, b, from the outer surface of the shell;
- plus the cross-sectional area of the stub projecting inside the shell within a distance, b, from the inner surface of the shell;
- plus the cross-sectional area of the welding fillets inside and outside the shell;

where

$b = \sqrt{d_a t_b}$
t_b = actual thickness of tube stub, in mm.

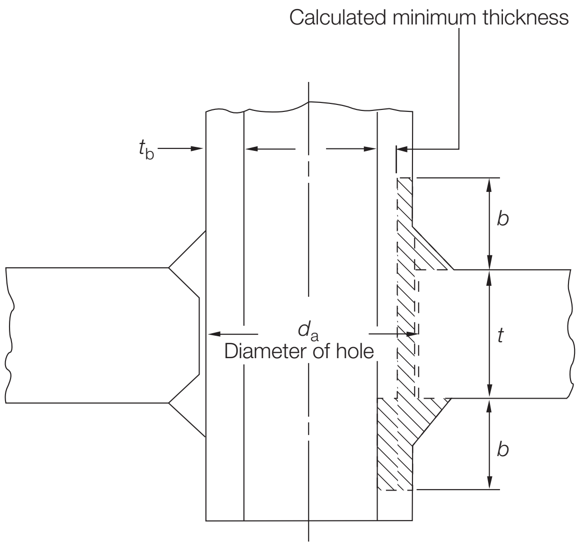


Fig. 10.2.7 Compensation of welded tube stubs
The calculated minimum thickness is to satisfy 7.1.

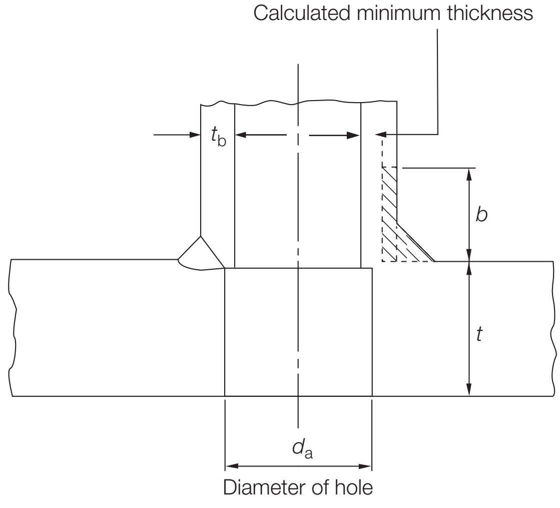


Fig. 10.2.8 Compensation of welded tube stubs
The calculated minimum thickness is to satisfy 7.1.

2.3.3 Where the material of the tube stub has an allowable stress lower than that of the shell, the compensating cross-sectional area of the stub is to be multiplied by the ratio:

$$\frac{\text{allowable stress of stub at design metal temperature}}{\text{allowable stress of shell at design metal temperature}}$$

2.4 Unreinforced openings

2.4.1 Openings in a definite pattern, such as tube holes, may be designed in accordance with the Rules for ligaments in 2.2, provided that the diameter of the largest hole in the group does not exceed that permitted by 2.4.2.

2.4.2 The maximum diameter, d, of any unreinforced isolated openings is to be determined by the following formula:

$$d = 8{,}08\,[D_o\, t\,(1 - K)]^{1/3} \text{ in mm}$$

The value of K to be used is calculated from the following formula:

$$K = \frac{p\,D_o}{18{,}2\,\sigma\,t} \text{ but is not to be taken as greater than 0,99}$$

where

p, D_o and σ are as defined in 1.2
t = actual thickness of shell, in mm.

2.4.3 For elliptical or oval holes, d, for the purposes of 2.4.2, refers to the major axis when this lies longitudinally or to the mean of the major and minor axes when the minor axis lies longitudinally.

2.4.4 No unreinforced opening is to exceed 200 mm in diameter.

2.4.5 Holes may be considered isolated if the centre distance between two holes on the longitudinal axis of a cylindrical shell is not less than:

$d + 1{,}1\sqrt{D\,t}$ with a minimum $5d$

d = diameter of openings in shell (mean diameter if dissimilarly sized holes involved)

D = mean diameter of shell

t = actual thickness of shell

Where the centre distance is less than so derived, the holes are to be fully compensated.

Where two holes are offset on a diagonal line, the diagonal efficiency from Fig. 10.2.6 may be used to derive an equivalent longitudinal centre distance for the purposes of this paragraph.

2.5 Reinforced openings

2.5.1 Openings larger than those permitted by 2.4 are to be compensated in accordance with Fig. 10.2.9(a) or (b). The following symbols are used in Fig. 10.2.9(a) and (b):

t_s = calculated thickness of a shell without joint or opening or corrosion allowance, in mm

t_d = thickness calculated in accordance with 7.1 without corrosion allowance, in mm

t_a = actual thickness of shell plate without corrosion allowance, in mm

t_b = actual thickness of standpipe without minus tolerances and corrosion allowance, in mm

t_r = thickness of added reinforcement, in mm

D_i = internal diameter of cylindrical shell, in mm

d_o = diameter of hole in shell, in mm

L = width of added reinforcement not exceeding D, in mm

C = $\sqrt{d_o\,t_b}$ in mm

D = $\sqrt{D_i\,t_a}$ and is not to exceed $0{,}5d_o$, in mm

σ = shell plate allowable stress, N/mm^2

σ_p = standpipe allowable stress, N/mm^2

σ_r = added reinforcement allowable stress, N/mm^2

σ_w = weld metal allowable stress, N/mm^2

NOTE

σ_p, σ_r and σ_w are not to be taken as greater than σ.

2.5.2 For elliptical or oval holes, the dimension on the meridian of the shell is to be used for d_o in 2.5.1.

2.5.3 Compensation is to be distributed equally on either side of the centreline of the opening.

2.5.4 The welds attaching standpipes and reinforcing plates to the shell are to be of sufficient size to transmit the full strength of the reinforcing areas and all other loadings to which they may be subjected.

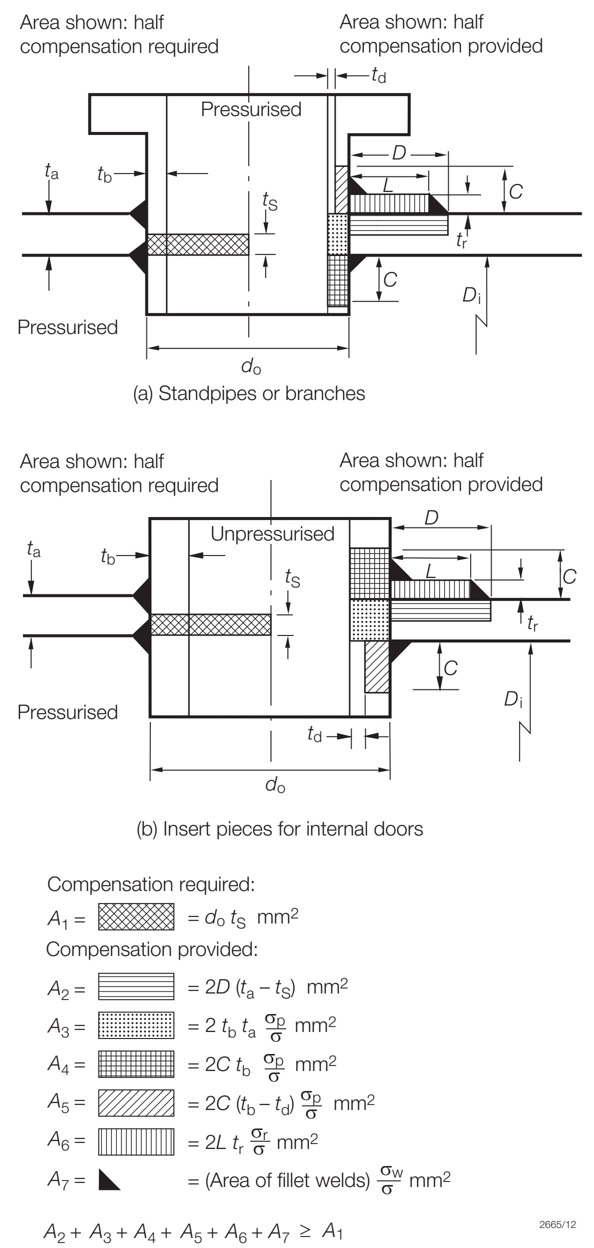


Fig. 10.2.9
Compensation for welded standpipes or branches in cylindrical shells

■ *Section 3*
Spherical shells subject to internal pressure

3.1 Minimum thickness

3.1.1 The minimum thickness of a spherical shell is to be determined by the following formula:

$$t = \frac{p\, R_i}{20\sigma\, J - 0{,}5p} + 0{,}75 \text{ mm}$$

where

t, p, R_i, σ and J are as defined in 1.2.

3.1.2 The formula in 3.1.1 is applicable only where the resulting thickness does not exceed half the internal radius.

3.1.3 Openings in spherical shells requiring compensation are to comply, in general, with 2.5, using the calculated and actual thicknesses of the spherical shell as applicable.

■ *Section 4*
Dished ends subject to internal pressure

4.1 Minimum thickness

4.1.1 The thickness, t, of semi-ellipsoidal and hemispherical unstayed ends, and the knuckle section of torispherical ends, dished from plate, having pressure on the concave side and satisfying the conditions listed below, is to be determined by the following formula:

$$t = \frac{p\, D_o\, K}{20\sigma\, J} + 0{,}75 \text{ mm}$$

where

t, p, D_o, σ and J are as defined in 1.2

K = a shape factor, *see* 4.2 and Fig. 10.4.1.

4.1.2 For semi-ellipsoidal ends:

the external height, $H \geq 0{,}18D_o$

where

D_o = the external diameter of the parallel portion of the end, in mm.

4.1.3 For torispherical ends:

the internal radius, $R_i \leq D_o$

the internal knuckle radius, $R_i \geq 0{,}1D_o$

the internal knuckle radius, $R_i \geq 3t$

the external height, $H \geq 0{,}18D_o$ and is determined as follows:

$$H = R_o - \sqrt{(R_o - 0{,}5D_o)(R_o + 0{,}5D_o - 2r_o)}\ .$$

4.1.4 In addition to the formula in 4.1.1 the thickness, t, of a torispherical head, made from more than one plate, in the crown section is to be not less than that determined by the following formula:

$$t = \frac{p\, R_i}{20\sigma\, J - 0{,}5p} + 0{,}75 \text{ mm}$$

where

t, p, R_i, σ and J are as defined in 1.2.

4.1.5 The thickness required by 4.1.1 for the knuckle section of a torispherical head is to extend past the common tangent point of the knuckle and crown radii into the cross-section for a distance not less than $0{,}5\sqrt{R_i\, t}$ mm, before reducing to the crown thickness permitted by 4.1.4, where

t = the required thickness from 4.1.1.

4.1.6 In all cases, H, is to be measured from the commencement of curvature, *see* Fig. 10.4.2.

4.1.7 The minimum thickness of the head, t, is to be not less than 6,0 mm.

4.1.8 For ends which are butt welded to the drum shell, *see* 1.8, the thickness of the edge of the flange for connection to the shell is to be not less than the thickness of an unpierced seamless or welded shell, whichever is applicable, of the same diameter and material and determined by 2.1.

4.2 Shape factors for dished ends

4.2.1 The shape factor, K, to be used in 4.1.1 is to be obtained from the curves in Fig. 10.4.1, and depends on the ratio of height to diameter $\frac{H}{D_o}$.

4.2.2 The lowest curve in the series provides the factor, K, for plain (i.e., unpierced) ends. For lower values of $\frac{H}{D_o}$, K depends upon the ratio of thickness to diameter, $\frac{t}{D_o}$, as well as on the ratio $\frac{H}{D_o}$, and a trial calculation may be necessary to arrive at the correct value of K.

4.3 Dished ends with unreinforced openings

4.3.1 Openings in dished ends may be circular, obround or approximately elliptical.

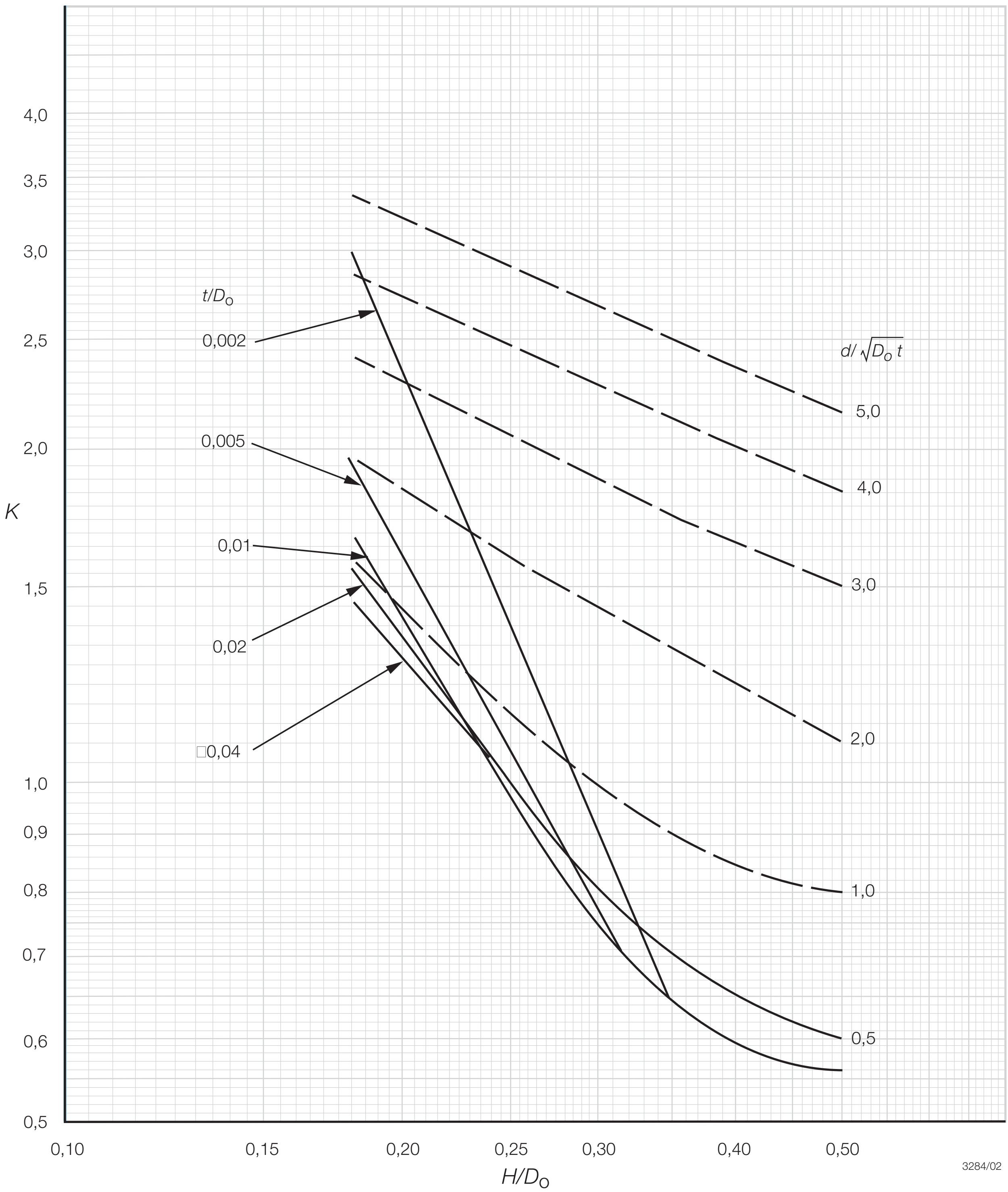


Fig. 10.4.1 Shape factor

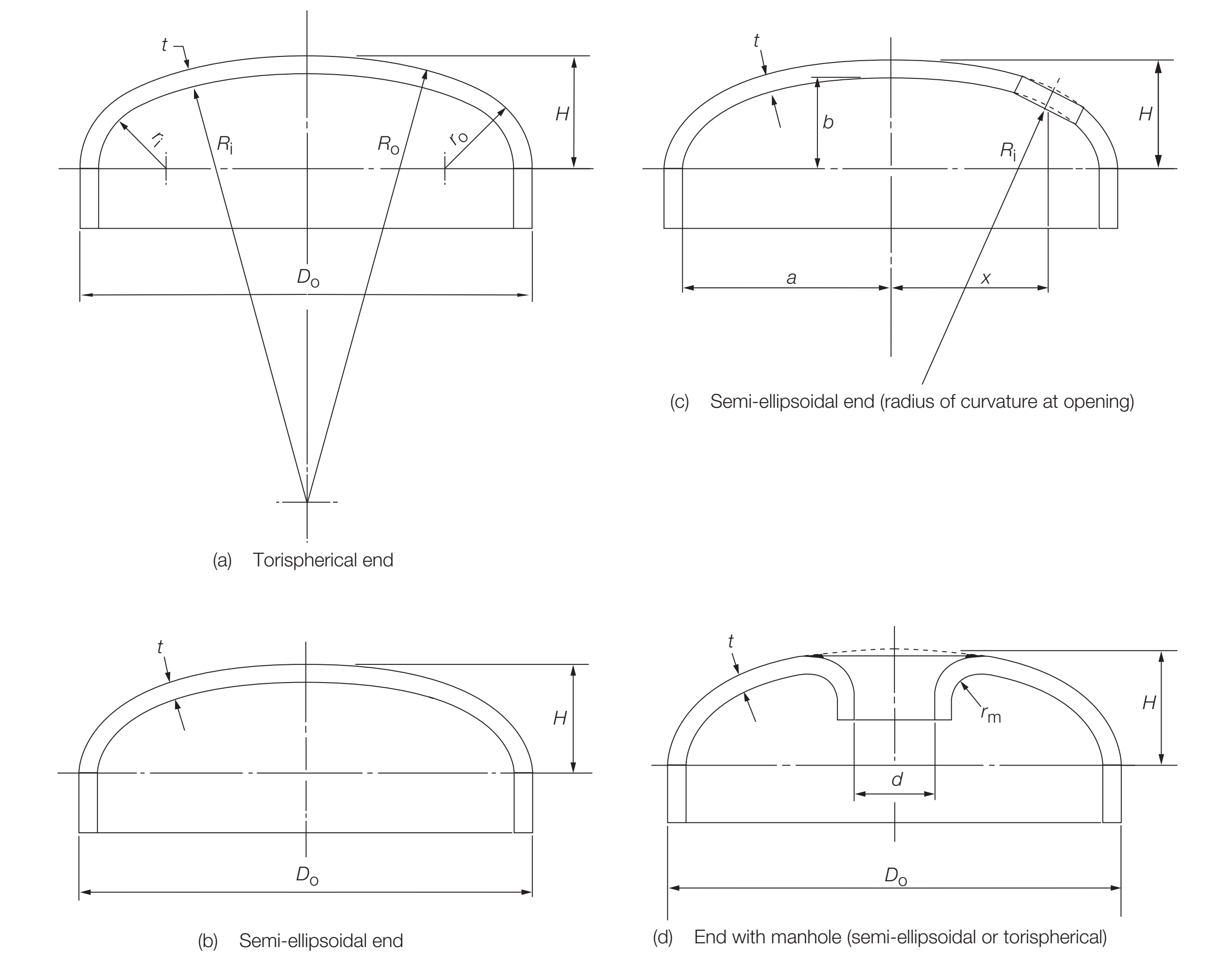


Fig. 10.4.2 Typical dished ends

4.3.2 The upper curves in Fig. 10.4.1 provide values of K, to be used in 4.1.1, for ends with unreinforced openings. The selection of the correct curve depends on the value $\frac{d}{\sqrt{D_o t}}$ and trial calculation is necessary to select the correct curve,

where

d = the diameter of the largest opening in the end plate, in mm (in the case of an elliptical opening, the larger axis of the ellipse)

t = minimum thickness, after dishing, in mm

D_o = outside diameter of dished end, in mm.

4.3.3 The following requirements must in any case be satisfied:

$$\frac{t}{D_o} \leq 0{,}1$$

$$\frac{d}{D_o} \leq 0{,}7.$$

4.3.4 From Fig.10.4.1 for any selected ratio of $\frac{H}{D_o}$ the curve for unpierced ends gives a value for $\frac{d}{\sqrt{D_o t}}$ as well as for K. Openings giving a value of $\frac{d}{\sqrt{D_o t}}$ not greater than the value so obtained may thus be pierced through an end designed as unpierced without any increase in thickness.

4.4 Flanged openings in dished ends

4.4.1 The requirements in 4.3 apply equally to flanged openings and to unflanged openings cut in the plate of an end. No reduction may be made in end plate thickness on account of flanging.

4.4.2 Where openings are flanged, the radius, r_m, of the flanging is to be not less than 25 mm, *see* Fig. 10.4.2(d). The thickness of the flanged portion may be less than the calculated thickness.

4.5 Location of unreinforced and flanged openings in dished ends

4.5.1 Unreinforced and flanged openings in dished ends are to be so arranged that the distance from the edge of the hole to the outside edge of the plate and the distance between openings are not less than those shown in Fig. 10.4.3.

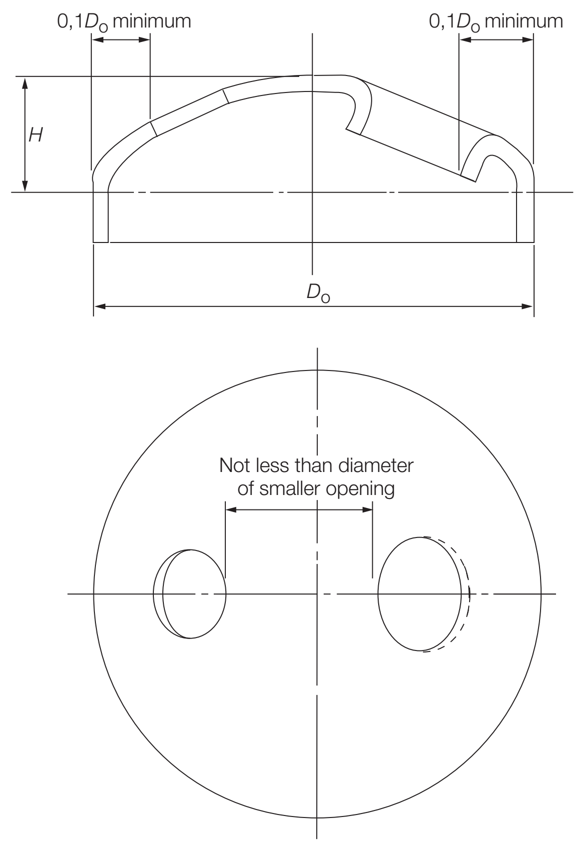


Fig. 10.4.3 Opening in dished ends

4.6 Dished ends with reinforced openings

4.6.1 Where it is desired to use a large opening in a dished end of less thickness than would be required by 4.3, the end is to be reinforced. This reinforcement may consist of a ring or standpipe welded into the hole, or of reinforcing plates welded to the outside and/or inside of the end in the vicinity of the hole, or a combination of both methods, *see* Fig. 10.4.4. Forged reinforcements may be used.

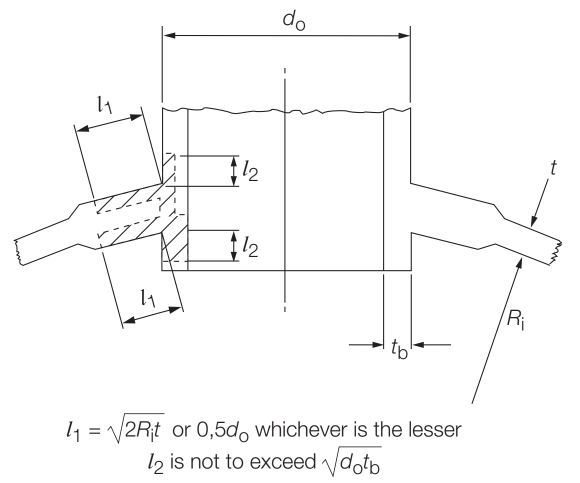


Fig. 10.4.4 Limits of reinforcement

4.6.2 Reinforcing material with the following limits may be taken as effective reinforcement:

(a) The effective width, l_1 of reinforcement is not to exceed $\sqrt{2R_i\, t}$ or 0,5d_o whichever is the lesser.

(b) The effective length, l_2 of a reinforcing ring is not to exceed $\sqrt{d_o\, t_b}$

where

R_i = the internal radius of the spherical part of a torispherical end, in mm, or

R_i = internal radius of the meridian of the ellipse at the centre of the opening, of a semi-ellipsoidal end, in mm, and is given by the following formula:

$$\frac{[a^4 - x^2\,(a^2 - b^2)]^{3/2}}{a^4\, b}$$

where

a, b and x are shown in Fig. 10.4.2(c)

d_o = external diameter of ring or standpipe, in mm

l_1 and l_2 are shown in Fig. 10.4.4

t_b = actual thickness of ring or standpipe, in mm.

4.6.3 The shape factor, K, for a dished end having a reinforced opening can be read from Fig. 10.4.1 using the value obtained from:

$$\frac{d_o - \dfrac{A}{t}}{\sqrt{D_o\, t}} \text{ instead of from } \frac{d}{\sqrt{D_o\, t}}$$

where

A = the effective cross-sectional area of reinforcement and is to be twice the area shown shaded on Fig. 10.4.4.

As in 4.3, a trial calculation is necessary in order to select the correct curve.

4.6.4 The area shown in Fig. 10.4.4 is to be obtained as follows:

- Calculate the cross-sectional area of reinforcement both inside and outside the end plate within the length, l_1
- plus the full cross-sectional area of that part of the ring or standpipe which projects inside the end plate up to a distance, l_2

- plus the full cross-sectional area of that part of the ring or standpipe which projects outside the internal surface of the end plate up to a distance, l_2, and deduct the sectional area which the ring or standpipe would have if its thickness were as calculated in accordance with 7.1.

4.6.5 If the material of the ring or the reinforcing plates has an allowable stress value lower than that of the end plate, then the effective cross-sectional area, *A*, is to be multiplied by the ratio:

$$\frac{\text{allowable stress of reinforcing plate at design temperature}}{\text{allowable stress of end plate at design temperature}}$$

4.7 Torispherical dished ends with reinforced openings

4.7.1 If an opening and its reinforcement are positioned entirely within the crown section, the compensation requirements are to be as for a spherical shell, using the crown radius as the spherical shell radius. Otherwise the requirements of 4.6 are to be applied.

■ *Section 5* Conical ends subject to internal pressure

5.1 General

5.1.1 Conical ends and conical reducing sections, as shown in Fig. 10.5.1, are to be designed in accordance with the equations given in 5.2.

5.1.2 Connections between cylindrical shell and conical sections and ends should preferably be by means of a knuckle transition radius. Typical permitted details are shown in Fig. 10.5.1. Alternatively, conical sections and ends may be butt welded to cylinders without a knuckle radius where the change in angle of slope, ψ, between the two sections under consideration does not exceed 30°.

5.1.3 Conical ends may be constructed of several ring sections of decreasing thickness, as determined by the corresponding decreasing diameter.

5.2 Minimum thickness

5.2.1 The minimum thickness, *t*, of cylinder, knuckle and conical section at the junction and within the distance, *L*, from the junction is to be determined by the following formula:

$$t = \frac{p\, D_o\, K}{20\sigma\, J} + 0{,}75 \text{ mm}$$

where

t, p, σ and J are as defined in 1.2

K = a factor, taking into account the stress in the knuckle, *see* Table 10.5.1.

D_o = outside diameter, in mm, of the conical section or end, *see* Fig. 10.5.1.

5.2.2 If the distance of a circumferential seam from the knuckle or junction is not to be less than *L*, then *J* is to be taken as 1,0; otherwise *J* is to be taken as the weld joint factor appropriate to the circumferential seam,

where

L = distance, in mm, from the knuckle or junction within which meridional stresses determine the required thickness, *see* Fig. 10.5.1

$= 0{,}5 \sqrt{\dfrac{D_o\, t}{\cos\psi}}$

r_i = inside radius of transition knuckle, in mm, which is to be taken as $0{,}01D_c$ in the case of conical sections without knuckle transition.

ψ = difference between angle of slope of two adjoining conical sections, *see* Fig. 10.5.1.

5.2.3 The minimum thickness, *t*, of those parts of conical sections not less than a distance, *L*, from the junction with a cylinder or other conical section is to be determined by the following formula:

$$t = \frac{p\, D_c}{(20\sigma\, J - p)} \; \frac{1}{\cos\alpha} + 0{,}75 \text{ mm}$$

where

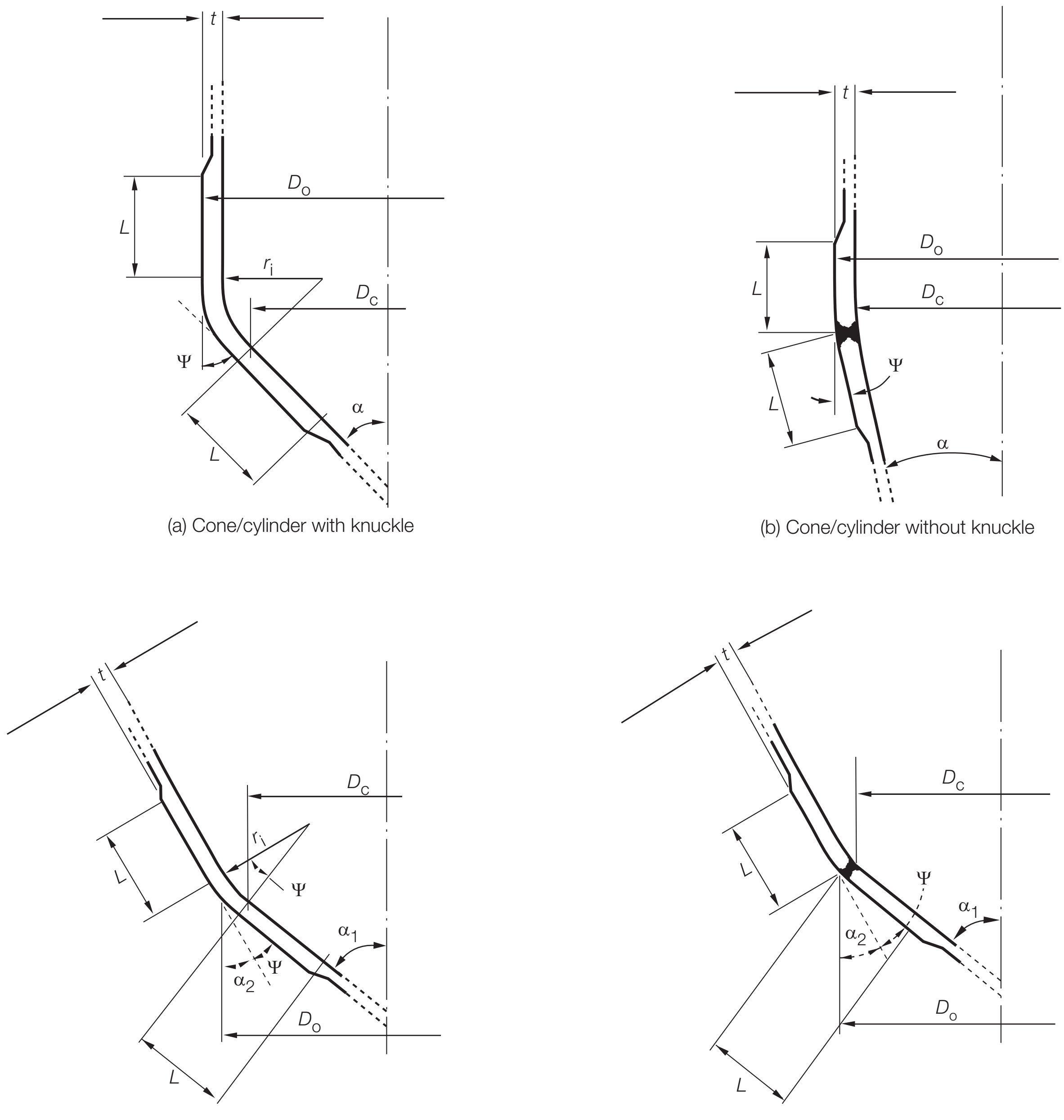
D_c = inside diameter, in mm of conical section or end at the position under consideration, *see* Fig. 10.5.1

$\alpha, \alpha_1, \alpha_2$ = angle of slope of conical section (at the point under consideration) to the vessel axis, *see* Fig. 10.5.1.

5.2.4 The greater of the two thicknesses determined by the formulae in 5.2.1 and 5.2.3 is to apply at the junction or knuckle and within the limits of reinforcement.

Table 10.5.1 Values of *K* as a function of ψ and r_i/D_o

ψ	Values of *K* for r_i/D_o ratios of 0,01	0,02	0,03	0,04	0,06	0,08	0,10	0,15	0,20	0,30	0,40	0,50
10°	0,70	0,65	0,60	0,60	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55
20°	1,00	0,90	0,85	0,80	0,70	0,65	0,60	0,55	0,55	0,55	0,55	0,55
30°	1,35	1,20	1,10	1,00	0,90	0,85	0,80	0,70	0,65	0,55	0,55	0,55
45°	2,05	1,85	1,65	1,50	1,30	1,20	1,10	0,95	0,90	0,70	0,55	0,55
60°	3,20	2,85	2,55	2,35	2,00	1,75	1,60	1,40	1,25	1,00	0,70	0,55
75°	6,80	5,85	5,35	4,75	3,85	3,50	3,15	2,70	2,40	1,55	1,00	0,55



(a) Cone/cylinder with knuckle

(b) Cone/cylinder without knuckle

(c) Cone/cone with knuckle

(d) Cone/cone without knuckle

Fig. 11.5.1 Conical ends and conical reducing sections

5.2.5 The thickness of conical sections having an angle of inclination to the vessel axis of more than 75° is to be determined as for a flat plate.

Section 6
Standpipes and branches

6.1 Minimum thickness

6.1.1 The minimum wall thickness of standpipes and branches is to be not less than that determined by 7.1 increased by the addition of a corrosion allowance of 0,75 mm, making such additions as may be necessary on account of bending, static loads and vibration. The wall thickness, however, is to be not less than:

$$t = 0{,}015D_o + 3{,}2 \text{ mm}$$

This thickness need only be maintained for a length, L, from the outside surface of the vessel, but need not extend past the first connection, butt weld or flange, where:

$$L = 3{,}5\sqrt{D_o\, t} \text{ mm}$$

where

t and D_o are as defined in 1.2.

6.1.2 For boilers having a working pressure exceeding 50 bar and safety valves of full lift or full bore type, the thickness of the branch pipe carrying the superheater or drum safety valves is to be not less than:

$$t = \frac{1}{\sigma}\left[1{,}7d + \frac{DWK}{1{,}3d^2}\right] \text{ mm}$$

where

t and σ are as defined in 1.2

d = inside diameter of branch, in mm

D = inside diameter of safety valve discharge, in mm

K = 2 for superheater safety valves

= 1 for drum safety valves

W = total valve throughput, in kg/h.

6.1.3 The offset from the centreline of the waste steam pipe to the centreline of the safety valve is not to exceed four times the outside diameter of the safety valve discharge pipe. The waste steam pipe system is to be supported and arrangements made for expansion, such that no direct loading is imposed on the safety valve chests and the effects of vibration are to be minimised.

6.1.4 The pipe or header which carries the superheater safety valve is to be suitably thickened, but is to be not less than the thickness required for the branch for a distance of $\sqrt{D_2\, t}$ on either side of the opening

where

t = thickness required for the branch

D_2 = inside diameter of the pipe or header.

6.1.5 Except as required by 6.1.4, in no case need the wall thickness exceed the minimum shell thickness as required by 2.1, 3.1 or 4.1 as applicable.

6.1.6 Where a standpipe or branch is connected by screwing, the thickness is to be measured at the root of the thread.

6.1.7 For boiler, superheater or economiser tubes, the minimum thickness of the drum or the header connection or tube stub is to be calculated as part of the tube, in accordance with 7.1.

Section 7
Boiler tubes subject to internal pressure

7.1 Minimum thickness

7.1.1 The minimum wall thickness of straight tubes subject to internal pressure is to be determined by the following formula:

$$t = \frac{p\, D_o}{20\sigma + p} \text{ mm}$$

where

t, p, D_o and σ are as defined in 1.2.

NOTES

1. Provision must be made for minus tolerances where necessary and also in cases where abnormal corrosion or erosion is expected in service. For bending allowances, *see* 7.2.
2. Thickness is in no case to be less than the minimum shown in Table 10.7.1.

Table 10.7.1 Minimum thickness of tubes

Nominal outside diameter of tube, in mm	Minimum thickness. in mm
≤ 38	1,75
> 38 > 50	2,16
≤ 50 ≤ 70	2,40
> 70 ≤ 75	2,67
> 75 ≤ 95	3,05
> 95 ≤ 100	3,28
> 100 ≤ 125	3,50

7.1.2 The minimum thickness of boiler, superheater, reheater and economiser tubes is to be determined by using the design stress appropriate to the mean wall temperature, which will be considered to be the metal temperature. Unless it is otherwise agreed between the manufacturer and LR, the metal temperature used to decide the value of σ for these tubes is to be determined as follows:

(a) The calculation temperature for boiler tubes is to be taken as not less than the saturated steam temperature, plus 25°C for tubes mainly subject to convection heat, or plus 50°C for tubes mainly subject to radiant heat.

(b) The calculation temperature for superheater and reheater tubes is to be generally taken as not less than the steam temperature expected in the part being considered, plus 35°C for tubes mainly subject to convection heat. For tubes mainly subject to radiant heat the calculation temperature is generally to be taken as not less than the steam temperature expected in the part being considered, plus 50°C, but the actual metal temperature expected is to be stated when submitting plans.

(c) The calculation temperature for economiser tubes is to be taken as not less than 35°C in excess of the maximum temperature of the internal fluid.

7.1.3 The minimum thickness of downcomer tubes and pipes which form an integral part of the boiler and which are not exposed to combustion gases is to comply with the requirements for steam pipes.

7.2 Tube bending

7.2.1 Where boiler, superheater, reheater and economiser tubes are bent, the resulting thickness of the tubes at the thinnest part is to be not less than that required for straight tubes, unless it can be demonstrated that the method of forming the bend results in no decrease in strength at the bend. The manufacturer is to demonstrate in connection with any new method of tube bending that this condition is satisfied.

7.2.2 Tube bending, and subsequent heat treatment, where necessary, is to be carried out so as to ensure that residual stresses do not adversely affect the strength of the tube for the design purpose intended.

■ *Cross-references*

For details of manholes, sight holes and doors, *see* 14.1.
For details of tube holes and fitting of tubes, *see* 14.6.

■ *Section 8* **Headers**

8.1 Circular section headers

8.1.1 The minimum thickness of circular section headers is to be calculated in accordance with the formula for cylindrical shells in 2.1.

8.2 Rectangular section headers

8.2.1 The thickness of the flat walls of rectangular section headers is to be determined at the centre of the sides, at all the lines of holes and at the corners. The minimum required is to be the greatest thickness determined by the following formula:

$$t = \frac{pn}{20\sigma J} + \sqrt{\frac{0{,}4Yp}{\sigma J_1}} + 0{,}75 \text{ mm}$$

where

t, p and σ are as defined in 1.2

n = one half of the internal width of the wall perpendicular to that under consideration, in mm, *see* Fig. 10.8.1(b)

J = ligament efficiency for membrane stresses determined in accordance with 8.2.3

J_1 = ligament efficiency for bending stresses determined in accordance with 8.2.3.

Y = a coefficient determined in accordance with 8.2.2. In all cases if the value of Y is negative, the sign is to be ignored.

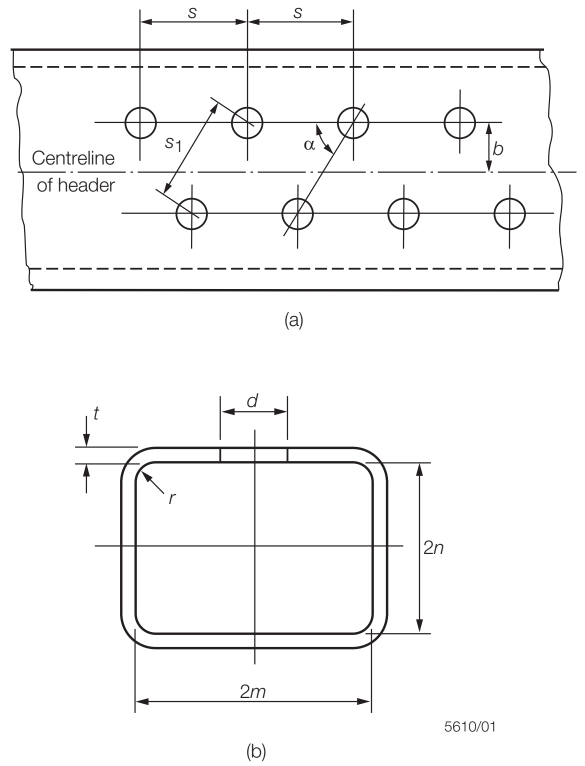


Fig. 10.8.1 Rectangular section headers

8.2.2 The coefficient Y for use in 8.2.1 is to be determined as follows:

(a) at the centre of the side with internal width, $2m$:

$$Y = \frac{1}{3}\left(\frac{m^3 + n^3}{m + n}\right) - \frac{1}{2} m^2$$

where

m = one half of the internal width of the wall under consideration, in mm, *see* Fig. 10.8.1(b)

(b) at a line of holes parallel to the longitudinal axis of the header on the wall of width, $2m$:

$$Y = \frac{1}{3}\left(\frac{m^3 + n^3}{m + n}\right) - \frac{m^2 - b^2}{2}$$

where

b = distance from the centre of the holes to the centreline of the wall, in mm, *see* Fig. 10.8.1(a)

(c) to check the effect of the off-set on a staggered hole arrangement where the holes are positioned equidistant from the centreline of the wall:

$$Y = \cos\alpha \left\{\frac{1}{3}\left(\frac{m^3 + n^3}{m + n}\right) - \frac{m^2}{2}\right\}$$

where

α = the angle subtended by the diagonal ligament on the longitudinal ligament, *see* Fig.10.8.1(a)

(d) at the corners:

$$Y = \frac{1}{3}\left(\frac{m^3 + n^3}{m + n}\right)$$

8.2.3 The ligament efficiencies J and J_1 are to be determined as follows:

(a) for a line of holes parallel to the longitudinal axis of the header:

$$J = \frac{s - d}{s}$$

Symbols are as defined in 8.2.4.

(b) for the diagonals:

$$J = \frac{s_1 - d}{s_1}$$

Symbols are as defined in 8.2.4.

(c) for a line of holes parallel to the longitudinal axis of the header:

$$J_1 = \frac{s - d}{s} \quad \text{when } d < 0{,}6m$$

or

$$J_1 = \frac{s - 0{,}6m}{s} \quad \text{when } d \geq 0{,}6m$$

Symbols are as defined in 8.2.4.

(d) for the diagonals:

$$J_1 = \frac{s_1 - d}{s_1} \quad \text{when } d < 0{,}6m$$

or

$$J_1 = \frac{s_1 - 0{,}6m}{s_1} \quad \text{when } d \geq 0{,}6m$$

Symbols are as defined in 8.2.4.

8.2.4 Symbols, as used in 8.2.3, are defined as follows:

d = diameter of the hole in the header, in mm

m, s and s_1, in mm, are as shown in Fig. 10.8.1.

8.2.5 In the case of elliptical holes the value of d to be used in the equations for J and J_1 is to be the inside dimension of the hole measured parallel to the longitudinal axis of the header. For evaluating the two limiting values of d in the equations for J_1, the value of d is to be the inside dimension of the hole measured perpendicular to the longitudinal axis of the header.

8.2.6 The internal corner radius, r, is to be not less than one third of the mean of the nominal thicknesses of the two sides, but in no case to be less than 6,5 mm.

8.3 Toroidal furnace headers

8.3.1 The minimum thickness of a toroidal header forming the lower end of a waterwall furnace, and supporting the weight of the boiler and water, is to be determined by the following formula:

$$t = A + \sqrt{A^2 + \frac{4M}{JS\,\sigma}} + 0{,}75 \text{ mm}$$

where

$$A = \frac{pr}{30J\,\sigma} \text{ mm}$$

t, p and σ are as defined in 1.2

d_e = equivalent diameter of the tube hole in accordance with 2.3

r = inside radius of toroid circular cross-section, in mm, *see* Fig. 10.8.3

J = ligament efficiency of tube holes around toroid

$$= \frac{S - d_e}{S}$$

S = pitch of tubes around the toroid, in mm

$$M = \frac{Wr}{3} - \frac{pd^2\,r}{40} \text{ Nmm}$$

where

W = imposed loading on each water wall tube due to the weight of the boiler and water, in N

d = minimum diameter of the tube hole in the toroid, in mm

The calculation is to be performed at design pressure using the allowable stress at saturation temperature, and also at zero pressure using the allowable stress at 100°C.

8.4 Header ends

8.4.1 The shape and thickness of ends forged integrally with the bodies of headers are to be the subject of special consideration.

8.4.2 Where sufficient experience of previous satisfactory service of headers with integrally forged ends cannot be shown, the suitability of a proposed form of end is to be proved in accordance with the provisions of 1.10.

8.4.3 Ends attached by welding are to be designed as follows:

- Dished ends: these are to be in accordance with 4.1.
- Flat ends: the minimum thickness of flat end plates is to be determined by the following formula:

$$t = d_i \sqrt{\frac{pC}{\sigma}} + 0{,}75 \text{ mm}$$

where

p and σ are as defined in 1.2.

t = minimum thickness of end plate, in mm

d_i = internal diameter of circular header or least width between walls of rectangular header, in mm

C = a constant depending on method of end attachment, *see* Fig. 10.8.2.

- For end plates welded as shown in Fig. 10.8.2(a):

C = 0,019 for circular headers
= 0,032 for rectangular headers.

- For end plates welded as shown in Figs. 10.8.2(b) and (c):

C = 0,028 circular headers
= 0,040 for rectangular headers.

8.4.4 Where flat end plates are bolted to flanges attached to the ends of headers, the flanges and end plates are to be in accordance with recognised pipe flange standards.

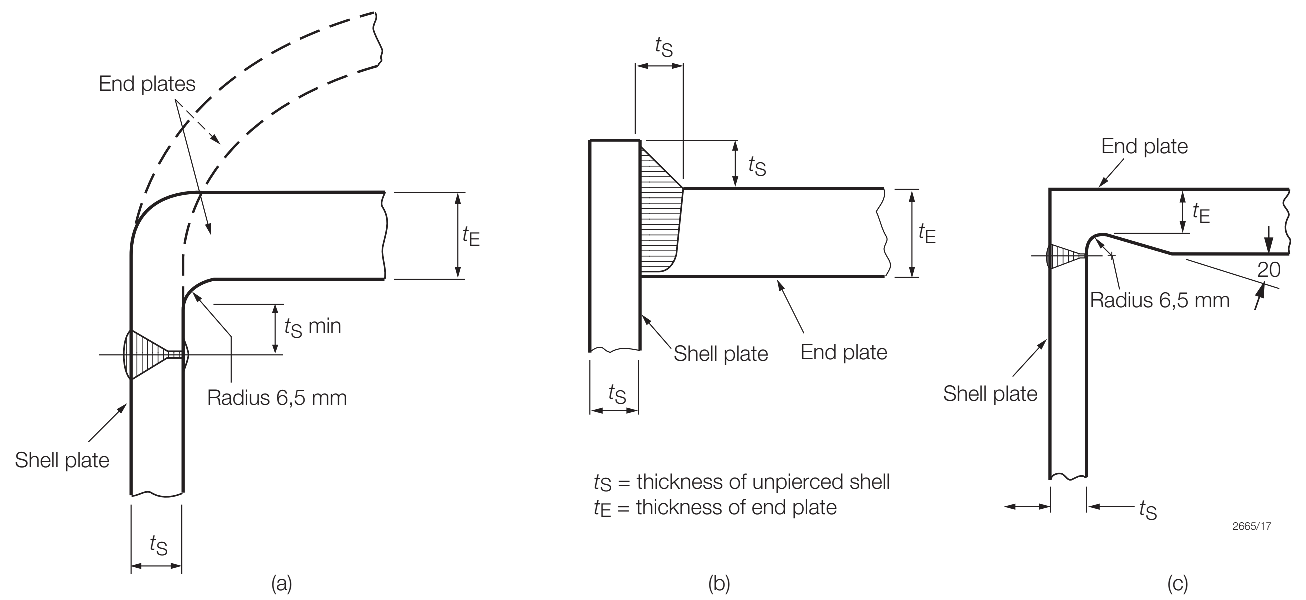


Fig. 10.8.2 Typical methods of attachment of header end closures

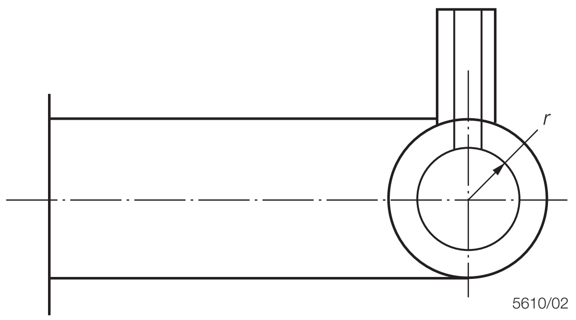


Fig. 10.8.3 Toroidal furnace headers

8.4.5 Openings in flat plates are to be compensated in accordance with Fig. 10.2.9 (a) or (b), with the value of A_1 the compensation required, calculated as follows:

$$A_1 = \frac{d_o}{2,4} t_f \text{ mm}$$

where

d_o = diameter of hole in flat plate, in mm

t_f = required thickness of the flat plate in the area under consideration, in mm, calculated in accordance with 8.4.3, 8.3.3 or 9.1.6, as applicable, without corrosion allowance

Limit D = $0,5d_o$.

■ *Section 9* Flat surfaces and flat tube plates

9.1 Stayed flat surfaces

9.1.1 Where flat end plates are flanged for connection to the shell, the inside radius of flanging is to be not less than 1,75 times the thickness of the plate, with a minimum of 38 mm.

9.1.2 Where combustion chamber or firebox plates are flanged for connection to the wrapper plate, the inside radius of flanging is to be equal to the thickness of the plate, with a minimum of 25 mm.

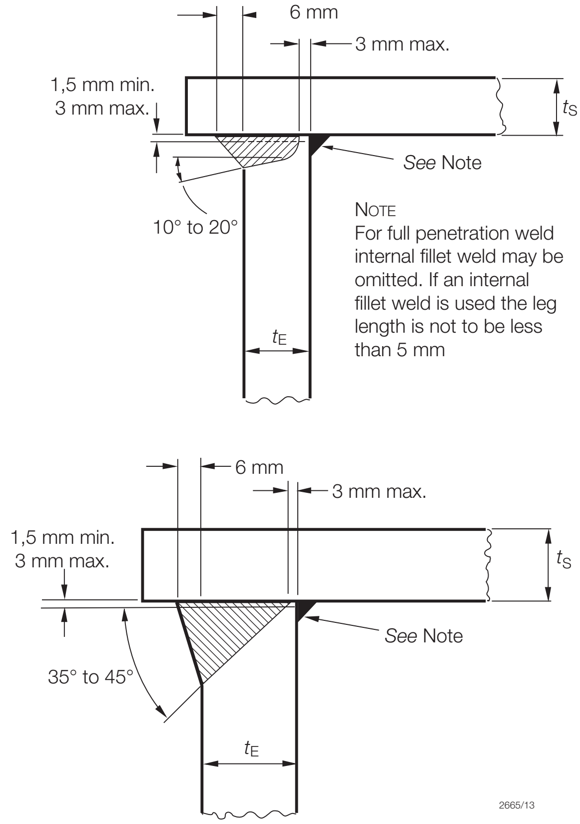
9.1.3 Where unflanged flat plates are connected to the shell by welding, typical methods of attachment are shown in Fig. 10.9.1. Similar forms of attachment may be used where unflanged combustion chamber or firebox plates are connected to the wrapper plate by welding.

9.1.4 Where the flange curvature is a point of support, this is to be taken at the commencement of curvature, or at a line distant 3,5 times the thickness of the plate from the outside of the plate, whichever is nearer to the flange.

9.1.5 Where a flat plate is welded directly to a shell or wrapper plate, the point of support is to be taken at the inside of the shell or wrapper plate.

9.1.6 The thickness, t, of those portions of flat plates supported by stays and around tube nests is to be determined by the following formula:

$$t = Cd\sqrt{\frac{p}{\sigma}} + 0,75 \text{ mm}$$



t_S = thickness of cylindrical shell
t_E = thickness of flat end

Fig. 10.9.1
Typical attachment of unflanged flat end plates to shell

where

t, p and σ are as defined in 1.2

d = diameter of the largest circle which can be drawn through at least three points of support. At least one point of support must lie on one side of any diameter of the circle

C = a constant, dependent on the method of support as detailed in 9.1.7. Where various forms of support are used, C is to be the mean of the values for the respective methods adopted.

9.1.7 The value of C in the formula in 9.1.6 is to be as follows:

(a) Where plain bar stays are strength welded into the plates as shown in Fig. 10.9.2
C = 0,134

(b) Where plain bar stays pass through holes in the plates and are fitted on the outside with washers as shown in Fig. 10.9.3
C = 0,12 where the diameter of the washer is 3,5 times the diameter of the stay
C = 0,113 where the diameter of the washer is 0,67 times the pitch of the stays.

(c) Where the flat plate is flanged for attachment to the shell, flue, furnace or wrapper or, alternatively, is welded directly to shell, flue, furnace or wrapper, *see* 9.1.4 and 9.1.5:
C = 0,113

(d) Where the support is a gusset stay
C = 0,134

(e) Where the support is a tube secured as shown in Fig. 10.9.4
C = 0,144.

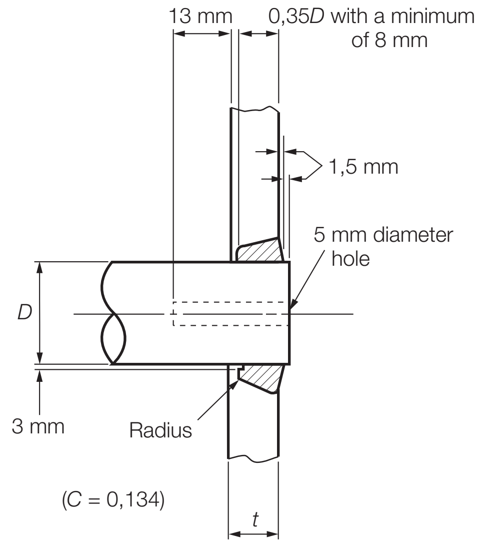
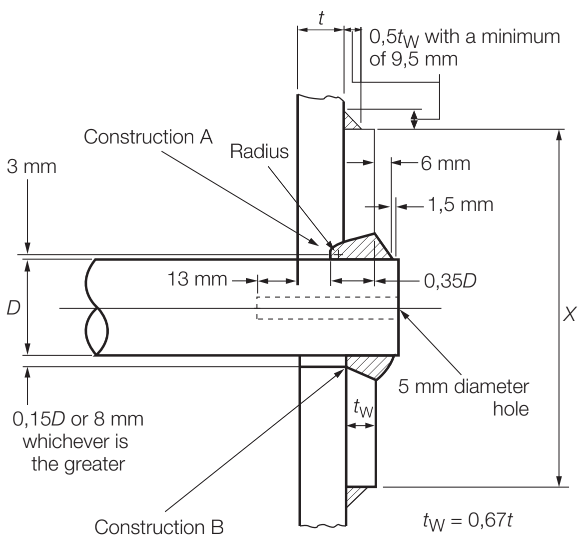


Fig. 10.9.2
Typical attachment of firebox, combustion chamber stays and bar stays

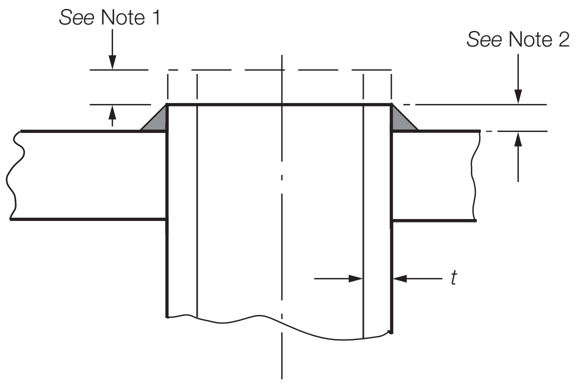


Method of construction 'A' or 'B' may be used, except where t_W < 0,35D, construction 'A' is to be used.

where X = 3,5D, C = 0,12;
where X = 0,67 x pitch of stays, C = 0,113

Fig. 10.9.3 Typical attachment of bar stays

9.1.8 Where tubes are fixed by expanding only, sufficient tubes welded at both ends in accordance with Fig. 10.9.4 are to be provided within the tube nest to comply with 9.1.6, to carry the flat plate loading within the tube nest. Tubes welded in accordance with Fig. 10.9.4 are also to be provided in the boundary rows in sufficient numbers to carry the flat plate loading outside the tube areas.



NOTE
1. The ends of the tubes are to be dressed flush with the welds when exposed to flame. When not exposed to flame the ends of the tubes may extend a maximum of 10 mm beyond the weld.
2. 3 mm minimum, but stress in weld due to nominal flat plate load carried by the tube not to exceed 70 N/mm^2. An equivalent recessed weld may be used.
3. Weld stress area is to be based on the weld throat area.

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Fig. 10.9.4 Detail of weld for tube

9.1.9 In the case of small boilers with a single tube nest of expanded tubes which does not exceed an area of 0,65 m^2, welded tubes need not be fitted provided the tubes are beaded at the inlet end. In this instance the support afforded by the expanded tubes is not to be taken to extend beyond the line enclosing the outer surfaces of the tubes except that, between the outside of the nest and the attachment of the end plate to shell, there may be an unsupported width equal to the flat plate margin, as given by the formula in 9.4.1. The required tube plate thickness within such a tube nest is to be determined using the formula in 9.1.6, where:

C = 0,154
d = four times the mean pitch, in mm, of the expanded tubes in the nest.

9.1.10 The thickness, t, of any tube plate in the tube area is to be not less than that required for the surrounding plate determined by 9.1.6 and in no case less than:

(a) 12,5 mm where the diameter of the tube hole does not exceed 50 mm, or
(b) 14 mm where the diameter of the tube hole is greater than 50 mm.

9.1.11 Alternative methods of support will be specially considered.

9.1.12 The spacing of tube holes is to be such that the minimum width, b, in mm of any ligament between tube holes is not less than:

for expanded tubes:
$b = 0{,}125d + 12{,}5$ mm
for welded tubes:
$b = 0{,}125d + 8$ mm

where
d = diameter of the hole drilled in the plate, in mm.

9.1.13 Where a flat plate has a manhole or sight hole and the opening is strengthened by flanging, the total depth, H, of the flange, measured from the outer surface of the plate, is to be not less than:

$$H = \sqrt{t\,W}$$

where
t = thickness of plate, in mm
H = depth of flange, in mm
W = minor axis of manhole or sight hole, in mm.

9.1.14 Where the flat top plates of combustion chambers are supported by welded-on girders, the equation in 9.1.6 is to apply as follows:

(a) In the case of welded-on girders provided with waterways
C = 0,144
$d = \sqrt{X^2 + Y^2}$
where
X = width of waterway in the girder plus the thickness of the girder, in mm
Y = pitch of girders, in mm.

(b) In the case of continuously welded-on girders
C = 0,175
$d = D$
where
D = distance between inside faces of girders, in mm.

9.2 Combustion chamber tube plates under compression

9.2.1 The thickness of combustion chamber tube plates under compression due to the pressure on the top plate, based on a compressive stress not exceeding 96 N/mm^2, is to be determined by the following formula:

$$t = \frac{pWs}{1930\,(s - d)} \text{ mm}$$

where
t and p are as defined in 1.2
d = internal diameter of the plain tubes, in mm
s = pitch of tubes, in mm, measured horizontally where tubes are chain pitched, or diagonally where the tubes are staggered pitched and the diagonal pitch is less than the horizontal pitch
W = internal width of the combustion chamber, in mm, measured from tube plate to back chamber plate.

9.3 Girders for combustion chamber top plates

9.3.1 The formula in 9.3.2 is applicable to plate girders welded to the top combustion chamber plate by means of a full penetration weld.

9.3.2 The thickness of steel plate girders supporting the tops of combustion chambers is to be determined by the following formula:

$$t = \frac{0{,}32p\, l^2\, s}{d^2\, R_{20}} \text{ mm}$$

where

t and p are as defined in 1.2

d = effective depth of girder, in mm

l = length of girder measured internally from tube plate to back chamber plate, in mm

s = pitch of the girders, in mm

R_{20} = specified minimum tensile strength of the girder plate, in N/mm^2.

9.4 Flat plate margins

9.4.1 The width of margin, b, of a flat plate which may be regarded as being supported by the shell, furnaces or flues to which the flat plate is attached is not to exceed that determined by the following formula:

$$b = C\,(t - 0{,}75)\sqrt{\frac{\sigma}{p}} \text{ mm}$$

where

p and σ are as defined in 1.2

t = thickness of the flat plate, in mm

b = width of margin, in mm

C = 3,12.

9.4.2 Where an unflanged flat plate is welded directly to the shell, furnaces or flues and it is not practicable to effect the full penetration weld from both sides of the flat plate, the constant C used in the formula in 9.4.1 is to be:

C = 2,38.

9.4.3 In the case of plates which are flanged, the margin is to be measured from the commencement of curvature of flanging, or from a line 3,5 times the thickness of the plate measured from the outside of the plate, whichever is nearer to the flange.

9.4.4 Where the flat plate is not flanged for attachment to the shell, furnaces or flues, the margin is to be measured from inside of the shell or the outside of the furnaces or flues, whichever is applicable.

9.4.5 In no case is the diameter, D, in mm, of the circle forming the boundary of the margin supported by the uptake of a vertical boiler to be greater than determined by the following formula:

$$D = \sqrt{\frac{345A}{p} + d^2}$$

where

p is as defined in 1.2

d = external diameter of uptake, in mm

d_i = internal diameter of uptake, in mm

A = cross-sectional area of the uptake tube material,

i.e., $\frac{\pi}{4}\,(d^2 - d_i^2)$ mm^2.

Section 10
Flat plates and ends of vertical boilers

10.1 Tube plates of vertical boilers

10.1.1 Where vertical boilers have a nest or nests of horizontal tubes, so that there is direct tension on the tube plates due to the vertical load on the boiler ends or to them acting as horizontal ties across the shell, the thickness of the tube plates in way of the outer rows of tubes is to be determined by the following formula:

$$t = \frac{pD}{5J\, R_{20}} + 0{,}75 \text{ mm}$$

where

t and p are as defined in 1.2

D = twice the radial distance of the centre of the outer row of tube holes from the axis of the shell, in mm

J = efficiency of ligaments between tube holes in the outer vertical rows (expressed as a fraction)

$= \frac{s - d}{s}$

R_{20} = specified minimum tensile strength of tube plate, in N/mm^2

where

d = diameter of tube holes, in mm

s = vertical pitch of tubes, in mm.

10.1.2 Each alternate tube in the outer vertical rows of tubes is to be a tube welded at both ends as shown in Fig. 10.9.4. Further, the arrangement of tubes in the nests is to be such that the thickness of the tube plates meets the requirements of 9.1.

10.1.3 Where the vertical height of the tube plates between the top and bottom shelves exceeds 0,65 times the internal diameter of the boiler, the staying of the tube plates, and the scantlings of the tube plates and shell plates to which the sides of the tube plates are connected, will require to be specially considered. It is recommended, however, that for this type of boiler the vertical height of the tube plates between the top and bottom shelves should not exceed 1,25 times the internal diameter of the boiler.

10.2 Horizontal shelves of tube plates forming part of the shell

10.2.1 For vertical boilers of the type referred to in 10.1, in order to withstand vertical load due to pressure on the boiler ends, the horizontal shelves of the tube plates are to be supported by gussets in accordance with the following formula:

$$C = \frac{AD_i\, p}{t}$$

where

p = design pressure, in bar

t = thickness of the tube plate, in mm

A = maximum horizontal dimension of the shelf from the inside of the shell plate to the outside of the tube plate, in mm

D_i = inside diameter of the boiler, in mm.

10.2.2 For the combustion chamber tube plate the minimum number of gussets is to be:
1 gusset, where C exceeds 255 000
2 gussets, where C exceeds 350 000
3 gussets where C exceeds 420 000.

10.2.3 For the smokebox tube plate the minimum number of gussets is to be:
1 gusset where C exceeds 255 000
2 gussets where C exceeds 470 000.

10.2.4 The shell plates to which the sides of the tube plates are connected are to be not less than 1,6 mm thicker than is required by the formula applicable to shell plates with continuous circularity, and where gussets or other stays are not fitted to the shelves, the strength of the parts of the circumferential seams at the top and bottom of these plates, from the outside of one tube plate to the outside of the other, is to be sufficient to withstand the whole load on the boiler end with a factor of safety of not less than 4,5 related to R_{20} (where R_{20} is the specified minimum tensile strength of the shell plates, in N/mm^2).

10.3 Dished and flanged ends for vertical boilers

10.3.1 The minimum thickness, t, of dished and flanged ends for vertical boilers which are subject to pressure on the concave side and are supported by central uptakes is to be determined by the following formula:

$$t = \frac{pR_i}{13\sigma} + 0{,}75 \quad \text{mm}$$

where
t, p, R_i and σ are as defined in 1,2.

10.3.2 The inside radius of curvature, R_i, of the end plate is to be not greater than the external diameter of the cylinder to which it is attached.

10.3.3 The inside knuckle radius, r_i, *see* Fig. 10.4.2(a), of the arc joining the cylindrical flange to the spherical surface of the end is to be not less than four times the thickness of the end plate, and in no case less than 65 mm.

10.3.4 The inside radius of curvature of flange to uptake is to be not less than twice the thickness of the end plate, and in no case less than 25 mm.

10.3.5 If the dished end has a manhole, the opening is to be strengthened by flanging. The total depth, H, of the flange, measured from the outer surface of the plate on the minor axis, is to be not less than:

$$H = \sqrt{t\,W}$$

where
t = thickness of the flange, in mm
H = depth of flange, in mm
W = minor axis of the manhole, in mm.

10.4 Flat crowns of vertical boilers

10.4.1 The minimum thickness of flat crown plates of vertical boilers is to be determined as in 9,1: d and C are defined as follows:

- Where the crown is supported by an uptake only,
  d = diameter, in mm, of the largest circle which can be drawn between the connections to the shell or firebox and uptake, *see* 9.1.1 to 9.1.5
  C = 0,161
- Where bar stays are fitted in accordance with 9.1.6 and 9.1.7:
  d = diameter of the largest circle which can be drawn through at least three points of support, in mm
  C = the mean of the values for the respective points of support through which the circle passes.

■ *Section 11* Furnaces subject to external pressure

11.1 Maximum thickness

11.1.1 Furnaces, plain or corrugated, are not to exceed 22,5 mm in thickness.

11.2 Corrugated furnaces

11.2.1 The minimum thickness, t, of corrugated furnaces is to be determined by the following formula:

$$t = \frac{pD_o}{C} + 0{,}75 \quad \text{mm}$$

where
p is as defined in 1.2
t = thickness of the furnace plate measured at the bottom of the corrugations, in mm
C = 1060 for Fox, Morison and Deighton corrugations
= 1130 for Suspension Bulb corrugations
D_o = external diameter of the furnace measured at the bottom of the corrugations, in mm.

11.3 Plain furnaces, flue sections and combustion chamber bottoms

11.3.1 The minimum thickness, t, between points of substantial support, of plain furnaces or furnaces strengthened by stiffening rings, of flue sections and of the cylindrical bottoms of combustion chambers is to be determined by the following formulae, the greater of the two thicknesses obtained being taken:

$$t = \sqrt{\frac{pD_o\,(L + 610)}{102\,400}} + 0{,}75 \quad \text{mm}$$

$$t = \frac{C\,p\,D_o}{1100} + \frac{L}{320} + 0{,}75 \quad \text{mm}$$

where

t and p are as defined in 1.2

$C = \dfrac{2x}{x + \sigma}$ or 0,85 whichever is the greater

D_o = external diameter of the furnace, flue or combustion chamber, in mm

L = length of section between the centres of points of substantial support, in mm

x and σ are as defined in 11.7.1.

11.3.2 Where stiffeners are used for strengthening plain cylindrical furnaces, or combustion chambers, the second moment of area, I, of the stiffener is to be determined by the following formula:

$$I = \frac{p D_o^3 L}{13{,}3 \times 10^6} \text{ mm}^4$$

where

p is as defined in 1.2

D_o = external diameter of the furnace flue or combustion chamber, in mm

L = length of section between the centres of points of substantial support, in mm

For proportion of stiffening rings, *see* Fig. 10.11.1.

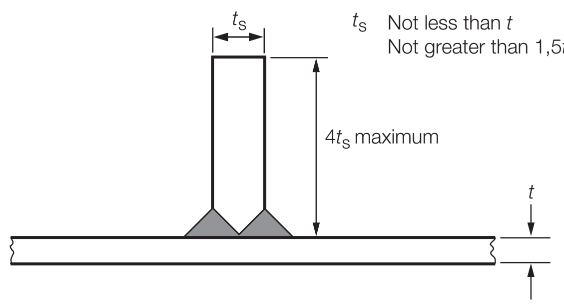


Fig. 10.11.1
Furnace, flue and combustion chamber stiffeners

11.4 Plain furnaces of vertical boilers

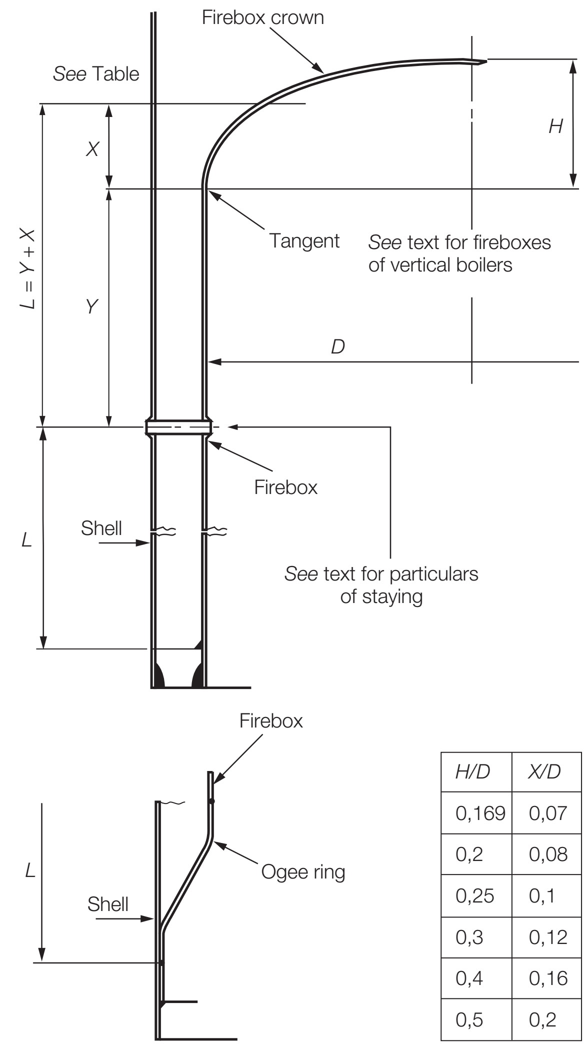
11.4.1 The thickness of plain furnaces not exceeding 2000 mm in external diameter is to be determined by the formulae given in 11.3.1, the greater of the two thicknesses being taken:

where

D_o = external diameter of the furnace, in mm. Where the furnace is tapered, the diameter to be taken for calculation purposes is to be the mean of that at the top and that at the bottom where it meets the substantial support from flange, ring or row of stays

L = effective length, in mm, of the furnace between the points of substantial support as indicated in Fig. 10.11.2.

11.4.2 For furnaces under 760 mm in external diameter, the thickness is to be not less than 8 mm, and for furnaces 760 mm in external diameter and over, the thickness is to be not less than 9,5 mm.



H/D	*X/D*
0,169	0,07
0,2	0,08
0,25	0,1
0,3	0,12
0,4	0,16
0,5	0,2

Fig. 10.11.2 Effective length, *L*, for use in 11.4

11.4.3 A circumferential row of stays connecting the furnace to the shell will be considered to provide substantial support to the furnace, provided that:

- The diameter of the stay is not less 22,5 mm or twice the thickness of the furnace, whichever is the greater.
- The pitch of the stays at the furnace does not exceed 14 times the thickness of the furnace.

11.5 Hemispherical furnaces

11.5.1 The minimum thickness, t, of unsupported hemispherical furnaces subject to pressure on the convex surface is to be determined by the following formula:

$$t = \frac{C\,p\,R_o}{608} + 0{,}75 \text{ mm}$$

where

t and p are as defined in 1.2

x and σ are as defined in 11.7.1

$C = \dfrac{2x}{x + \sigma}$ or 0,85 whichever is the greater

R_o = outer radius of curvature of the furnace, in mm.

11.5.2 In no case is the maximum thickness to exceed 22,5 mm, or the ratio $\dfrac{R_o}{t - 0{,}75}$ to exceed 100.

11.6 Dished and flanged ends for supported vertical boiler furnaces

11.6.1 The minimum thickness, t, of dished and flanged ends for vertical boiler furnaces that are subject to pressure on the convex side and are supported by central uptakes, is to be determined by the following formula:

$$t = \frac{p\,R_o}{10\sigma} + 0{,}75 \text{ mm}$$

where

t, p, R_o and σ are as defined in 1.2.

11.6.2 The inside radius of dishing and flanging are to be as required by 10.3.

11.7 Dished and flanged ends for unsupported vertical boiler furnaces

11.7.1 The minimum thickness, t, of dished and flanged ends for vertical boiler furnaces that are subject to pressure on the convex side and are without support from stays of any kind, is to be determined by the following formula, but is in no case to be less than the thickness of the firebox:

$$t = \frac{CpR_o}{660} + 0{,}75 \text{ mm}$$

where

t and p are as defined in 1.2.

x = specified minimum lower yield stress or 0,2 per cent proof stress in N/mm^2 at a temperature 90°C above the saturated steam temperature corresponding to the design pressure for carbon and carbon manganese steel with a specified minimum tensile strength of 400 N/mm^2

$C = \dfrac{2x}{x + \sigma}$ or 0,85 whichever is the greater

R_o = outside radius of the crown plate, in mm $\left(\text{in no case is } \dfrac{R_o}{t} \text{ to exceed 88}\right)$

σ = specified minimum lower yield stress or 0,2 per cent proof stress in N/mm^2 at a temperature 90°C above the saturated steam temperature corresponding to the design pressure for the steel actually used.

11.7.2 The inside radius of curvature, R_i, of the end plate is to be not greater than the external diameter of the cylinder to which it is attached.

11.7.3 The inside knuckle radius, r_i, *see* Fig.10.4.2(a), of the arc joining the cylindrical flange to the spherical surface of the end is to be not less than four times the thickness of the end plate and in no case less than 65 mm.

11.8 Ogee rings

11.8.1 The minimum thickness, t, of the ogee ring which connects the bottom of the furnace to the shell of a vertical boiler and sustains the whole vertical load on the furnace is to be determined by the following formula:

$$t = \sqrt{\frac{p\,D_i\,(D_i - D_o)}{9\,900}} + 0{,}75 \text{ mm}$$

where

t and p are as defined in 1.2

D_i = inside diameter of boiler shell, in mm

D_o = outside diameter of the lower part of the furnace where it joins the ogee ring, in mm.

11.8.2 Proposals to use a flat plate annular ring which connects the bottom of the furnace to the shell of a vertical boiler and sustains any unbalanced vertical load on the furnace will be the subject of special consideration.

11.9 Uptakes of vertical boilers

11.9.1 The minimum thickness, t, of internal uptakes of vertical boilers is to be determined by the following formulae, the greater of the two thicknesses obtained being taken:

$$t = \sqrt{\frac{p\,D_o\,(L + 610)}{102\,400}} + 4 \text{ mm}$$

$$t = \frac{p\,D_o}{1100} + \frac{L}{320} + 4 \text{ mm}$$

where

t and p are as defined in 1.2

D_o = external diameter of uptake, in mm

L = length of uptake between the centres of points of substantial support, in mm.

■ *Section 12*
Boiler tubes subject to external pressure

12.1 Tubes

12.1.1 The thickness of tubes is to be in accordance with Table 10.12.1 for the appropriate outside diameter and design pressure.

12.1.2 Tubes may be welded at both ends, welded at the inlet end and expanded at the outlet end, or expanded at both ends. In addition to expanding, tubes may be bell mouthed or beaded at the inlet end. Where tubes are welded, the weld detail is to be as shown in Fig. 10.9.4 and the tubes are to be expanded into the tube plates in addition to welding, except as permitted by 12.1.3.

12.1.3 For tubes of thickness greater than 6,0 mm, expanding in addition to welding is not required if a recessed weld of depth not less than the tube thickness is provided.

■ *Section 13*
Tubes welded at both ends and bar stays for cylindrical boilers

13.1 Loads on tubes welded at both ends and bar stays

13.1.1 Each tube or bar stay is to be designed to carry its due proportion of the load on the plates which it supports.

13.1.2 For a tube or bar stay, the net area to be supported is to be the area, in mm^2, enclosed by the lines bisecting at right angles the lines joining the stay and the adjacent points of support, less the area of any tubes or stays enclosed. In the case of a tube or bar stay in the boundary rows, the support afforded by the flat plate margin, where applicable, should be taken into account. Where flat margins overlap stays are not required.

13.1.3 The thickness of tubes welded at both ends to tube plates is to be such that the longitudinal stress due to the flat plate loading does not exceed 70 N/mm^2.

13.1.4 Tubes may be welded into the boiler after post-weld heat treatment has been carried out.

13.1.5 The permissible longitudinal stress in combustion chamber bar stays or similar stays where an end is heated by flame, is not to exceed 70 N/mm^2, and the diameter of this type of bar stay is not to be less than 19 mm.

13.1.6 The permissible longitudinal stress in longitudinal bar stays not subject to heating, is not to exceed 20 per cent of the minimum specified tensile strength, in N/mm^2, and the diameter of this type of bar stay is not to be less than 25 mm.

Table 10.12.1 Thickness of plain tubes under external pressure

Design pressure, in bar											Thickness, in mm
Outside diameter, in mm											
38	44,5	51	57	63,5	70	76	82,5	89	95	102	
–	–	–	–	–	–	–	–	–	26,9	25,2	5,89
–	–	–	–	–	–	–	26,2	24,1	22,8	21,4	5,38
–	–	–	–	–	–	24,1	22,1	20,7	19,3	17,9	4,88
–	–	–	27,6	24,8	22,8	20,7	19,3	17,9	16,6	15,9	4,47
–	29,3	25,5	22,8	20,7	18,9	17,3	15,9	14,8	13,7	12,7	4,06
26,6	22,8	20,7	17,9	15,9	14,8	13,1	12,4	11,4	10,3	9,6	3,66
20,3	16,9	14,8	13,1	12,1	11,0	9,6	8,9	8,2	7,6	6,9	3,25
14,8	12,4	10,7	9,6	8,6	7,6	—	—	—	—	—	2,95

■ *Section 14* **Construction**

14.1 Access arrangements

14.1.1 In watertube boilers, manholes are to be provided in all drums of sufficient size to allow access for internal examination and cleaning, and for fitting and expanding the tubes. In the case of headers for water walls, superheaters or economisers, and of drums which are too small to permit entry, sight holes or mudholes sufficiently large and numerous for these purposes are to be provided.

14.1.2 Cylindrical boilers are to be provided, where possible with means for ingress to permit examination and cleaning of the inner surfaces of plates and tubes exposed to flame. Where the boilers are too small to permit this, there are to be sight holes and mudholes sufficiently large and numerous to allow the inside to be satisfactorily cleaned.

14.1.3 Where the cross tubes of vertical boilers are large, there is to be a sight hole in the shell opposite to one end of each tube sufficiently large to allow the tube to be examined and cleaned. These sight holes are to be in positions accessible for that purpose.

14.1.4 Manholes in cylindrical shells should preferably have their shorter axes arranged longitudinally.

14.1.5 Doors for manholes, mudholes and sight holes are to be formed from steel plate or other approved construction, and all jointing surfaces are to be machined.

14.1.6 Doors of the internal type are to be provided with spigots which have a clearance of not more than 1,5 mm all round, i.e., the axes of the opening are not to exceed those of the door by more than 3 mm. The width of the manhole gasket seat is to be not less than 16 mm.

14.1.7 Doors of the internal type for openings not larger than 230 mm x 180 mm need be fitted with one stud only, which may be forged integral with the door. Doors for openings larger than 230 mm x 180 mm are to be fitted with two studs or bolts. The strength of the attachment to the door is to be not less than the strength of the stud or bolt.

14.1.8 The crossbars or dogs for doors are to be of steel.

14.1.9 For smaller circular openings in headers and similar fittings, an approved type of plug may be used.

14.1.10 Circular flat cover plates may be fitted to raised circular manhole frames not exceeding 400 mm diameter, and for an approved design pressure not exceeding 18 bar.

14.1.11 External circular flat cover plates are to be in accordance with a recognised National Standard.

14.2 Torispherical and semi-ellipsoidal ends

14.2.1 For typical acceptable types of attachment for dished ends to cylindrical shells, *see* Fig. 10.14.1.

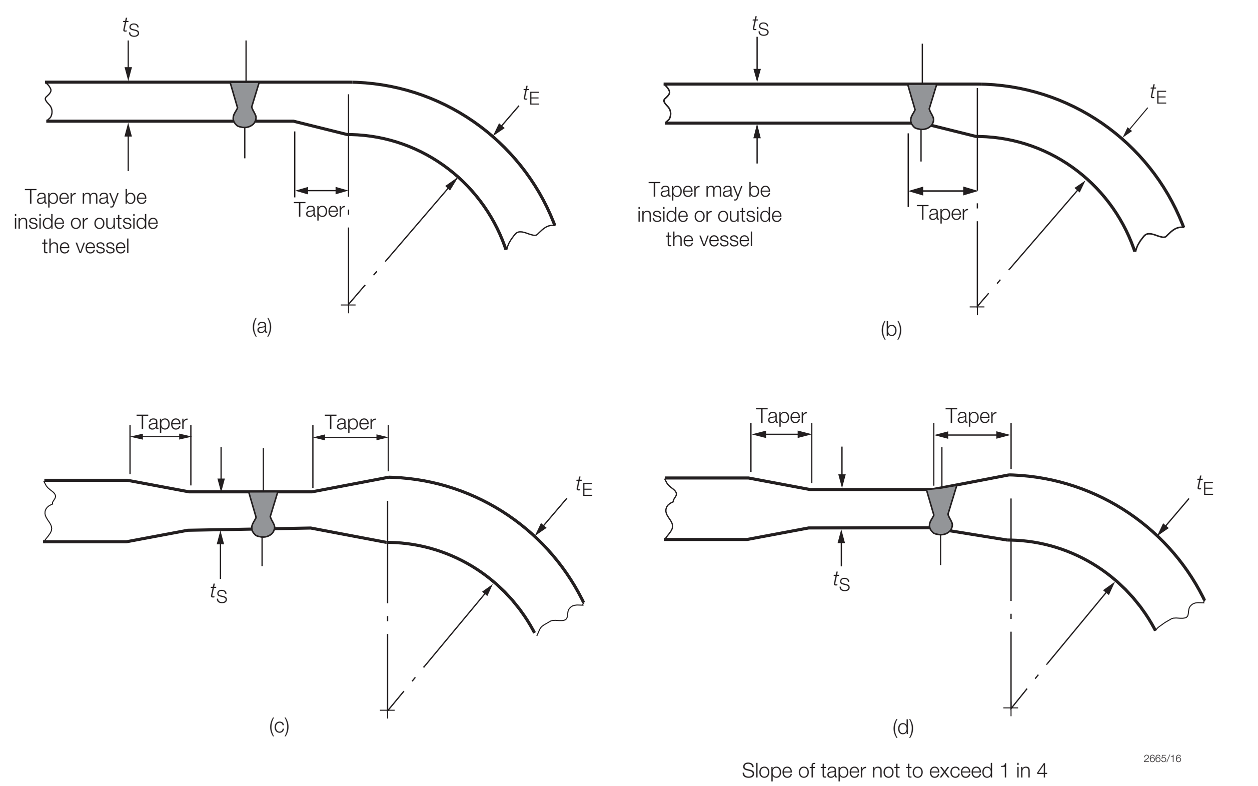


Fig. 10.14.1 Typical attachments of dished ends to cylindrical shells

14.2.2 Where the difference in thickness is the same throughout the circumference, the thicker plate is to be reduced in thickness by machining to a taper for a distance not less than four times the offset, so that the two plates are of equal thickness at the position of the circumferential weld. A parallel portion may be provided between the end of the taper and weld edge preparation; alternatively, if so desired, the width of the weld may be included as part of the smooth taper of the thicker plate.

14.2.3 The thickness of the plates at the position of the circumferential weld is to be not less than that of an unpierced cylindrical shell of seamless or welded construction, whichever is applicable, of the same diameter and material, *see* 4.1.

14.3 Hemispherical ends

14.3.1 Where hemispherical ends are butt welded to cylindrical shells, the thickness of the shell is to be reduced by taper to that of the end, and the centre of the hemisphere is to be so located that the entire tapered portion of the shell and the butt weld are within the hemisphere, *see* Fig. 10.14.2.

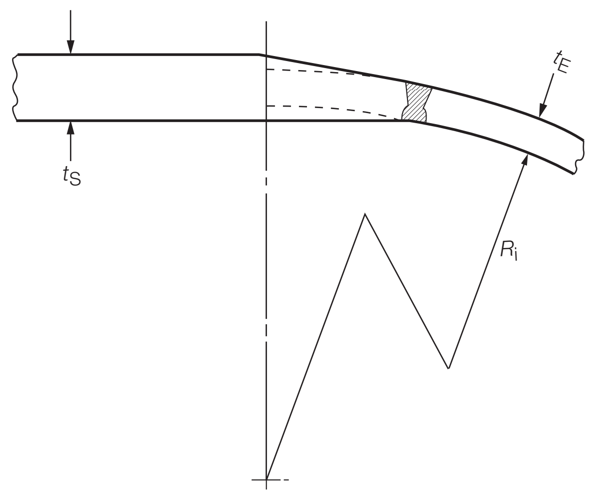


Fig. 10.14.2
Attachment of hemispherical end to cylindrical shell

14.3.2 If the hemispherical end is provided with a parallel portion, the thickness of this portion is to be not less than that of a seamless or welded shell, whichever is applicable, of the same diameter and material.

14.4 Welded-on flanges, butt welded joints and fabricated branch pieces

14.4.1 Flanges may be cut from plates or may be forged or cast. Hubbed flanges are not to be machined from plate. Flanges are to be attached to branches by welding. Alternative methods of flange attachment will be subject to special consideration.

14.4.2 The types of welded-on flanges are to be suitable for the pressure, temperature and service for which the branches are intended.

14.4.3 Flange attachments and pressure-temperature ratings in accordance with materials and design of recognised Standards will be accepted.

14.4.4 Typical examples of welded-on flange connections are shown in Fig. 10.14.3(a) to (f), and limiting design conditions for the flange types are shown in Table 10.14.1. In Fig. 10.14.3 *t* is the minimum Rule thickness of the standpipe or branch.

14.4.5 Welded-on flanges are not to be a tight fit on the branch. The maximum clearance between the bore of the flange and the outside diameter of the branch is to be 3 mm at any point, and the sum of the clearances diametrically opposite is not to exceed 5 mm.

14.4.6 Where butt welds are employed in the attachment of flange type (a), or in the construction of standpipes or branch pieces, the adjacent pieces are to be matched at the bores. This may be effected by drifting, roller expanding or machining, provided the pipe wall is not reduced below the designed thickness. If the parts to be joined differ in wall thickness, the thicker wall is to be gradually tapered to that of the thinner at the butt joint.

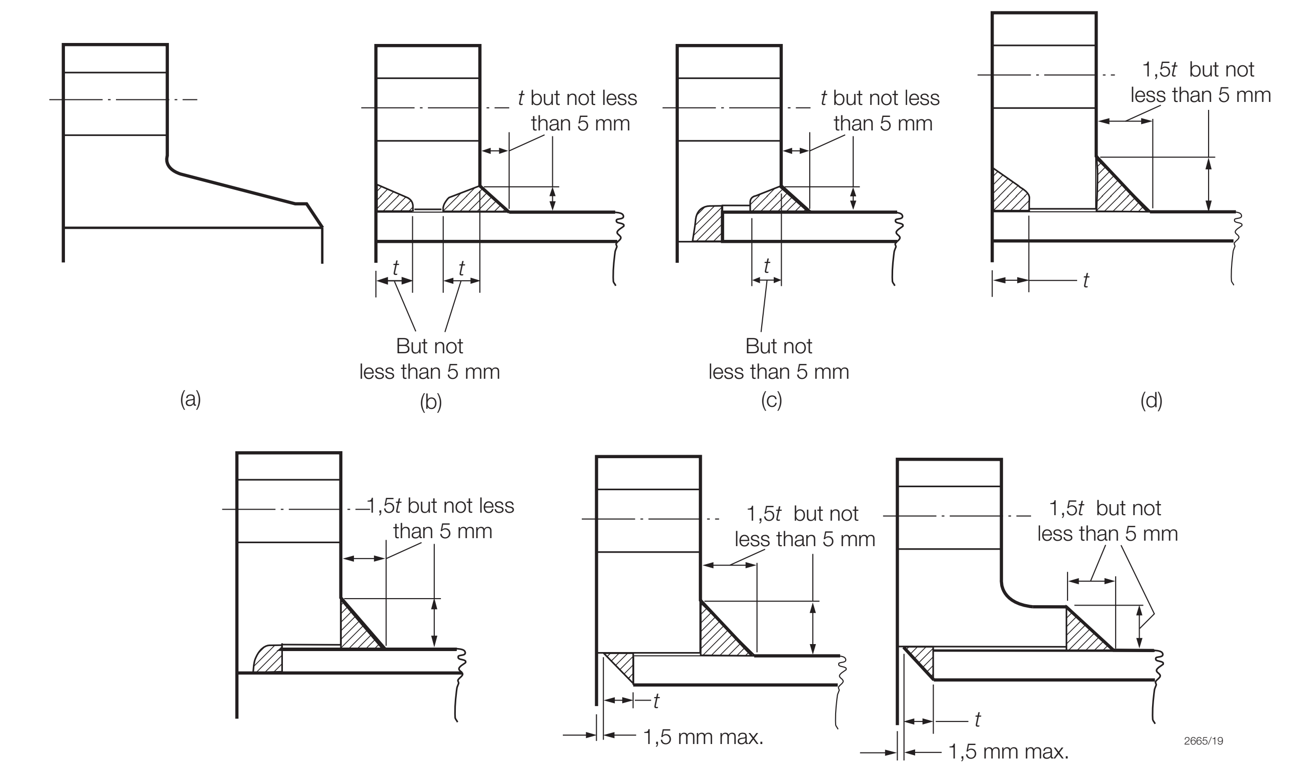
14.4.7 Welding may be carried out by means of the shielded metal arc, inert gas metal arc, oxy-acetylene or other approved process, but in general, oxy-acetylene welding is suitable only for flange type (a) and is not to be applied to branches exceeding 100 mm diameter or 9,5 mm thick. The welding is to be carried out in accordance with the appropriate paragraphs of Chapter 17.

14.4.8 Threaded sleeve joints complying with Ch 12,2.8.1 may be used on the steam and water piping of small oil fired package boilers of the once through coil type, used for auxiliary or domestic purposes, where the feed pump capacity limits the output.

14.4.9 Socket weld joints are not to be used where fatigue, severe erosion, crevice corrosion or stress corrosion is expected to occur, for example, blow down, drain, scum and chemical dosing connections.

14.5 Welded attachments to pressure vessels

14.5.1 Unless the actual thickness of the shell or end is at least twice that required by calculation for a seamless shell or end, whichever is applicable, doubling plates with well rounded corners are to be fitted in way of attachments such as lifting lugs, supporting brackets and feet, to minimise load concentrations on pressure shells and ends. Compensating plates, pads, brackets and supporting feet are to be bedded closely to the surface before being welded, and are to be provided with a 'tell-tale' hole not greater than 9,5 mm in diameter, open to the atmosphere to provide for the release of entrapped air during heat treatment of the vessel, or as a means of indicating any leakage during hydraulic testing and in service, *see* Chapter 17.



't' is the minimum Rule thickness of standpipe or branch

Fig. 10.14.3 Typical examples of welded flange connections

Table 10.14.1 Limiting design conditions for flanges

Flange type	Maximum pressure	Maximum temperature	Maximum pipe o.d.	Minimum pipe bore
		°C	mm	mm
(a)	Pressure-temperature ratings to be in accordance with a recognised Standard	No restriction	No restriction	No restriction
(b)		No restriction	168,3 for alloy steels*	No restriction
(c)		No restriction	168,3 for alloy steels*	75
(d)		425	No restriction	No restriction
(e)		425	No restriction	75
(f)		425	No restriction	No restriction

* No restriction for carbon steels

14.5.2 For acceptable methods of attaching standpipes, branches, compensating plates and pads, *see* Fig. 10.14.4. Alternative methods of attachment may be accepted provided details are submitted for consideration.

14.5.3 Where fillet welds are used to attach standpipes or set-in pads, there are to be equal sized welds both inside and outside the vessel, *see* Fig 10.14.4(a) and (l). The leg length of each of the fillet welds is to be not less than 1,4 times the actual thickness of the thinner of the parts being joined.

14.6 Fitting of tubes in water tube boilers

14.6.1 The tube holes in drums or headers are to be formed in such a way that the tubes can be effectively tightened in them. Where the tube ends are not normal to the tube plates, there is to be a neck or belt of parallel seating of at least 13 mm in depth, measured in a plane through the axis of the tube at the holes. Where the tubes are practically normal to their plates, this parallel seating is to be not less than 9,5 mm in depth.

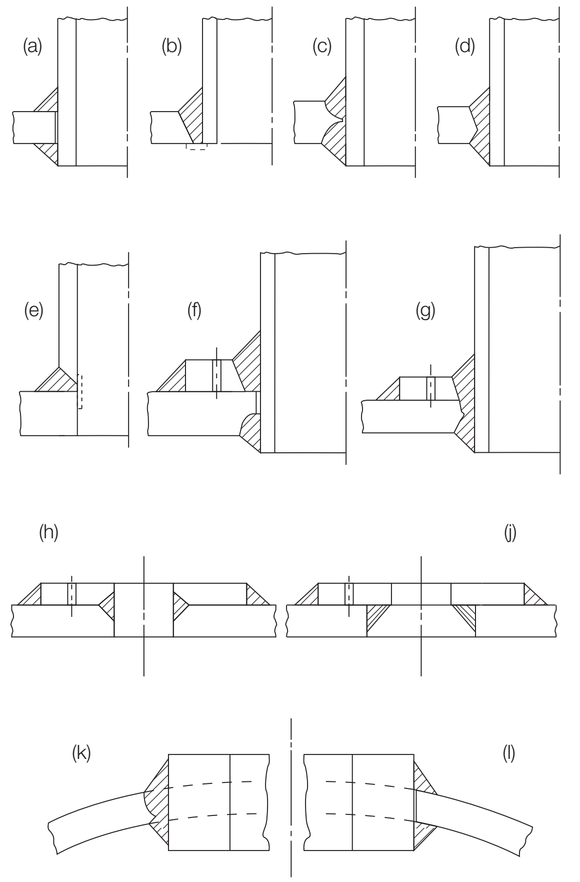


Fig. 10.14.4
Typical acceptable methods of attaching branches and pads

14.6.2 Tubes are to be carefully fitted in the tube holes and secured by means of welding, expanding and belling or by other approved methods. Tubes are to project through the neck or belt of parallel seating by at least 6 mm and where they are secured from drawing out by means of bellmouthing only, the included angle of belling is to be not less than 30°.

■ *Section 15*
Mountings and fittings for cylindrical and vertical boilers, steam generators, pressurised thermal liquid and pressurised hot water heaters

15.1 General

15.1.1 Valves over 38 mm diameter are to be fitted with outside screws, and the covers are to be secured by bolts or studs. All valves are to be arranged to shut with a right-hand (clockwise) motion of the wheels.

15.1.2 All valves and cocks connected to the boiler are to be such that it is seen without difficulty whether they are open or shut. Where boiler mountings are secured by studs, the studs are to have a full thread holding in the plate for a length of at least one diameter.

15.1.3 Where a superheater is fitted which can be shut off from the boiler, it is to be provided with a separate safety valve fitted with easing gear. The valve as regards construction is to comply with the regulations for ordinary safety valves, but the easing gear may be fitted to be workable from the stokehold only. The superheater is also to be fitted with a drain valve or cock to free it from water when necessary.

15.1.4 Safety valve chests and other boiler and superheater mountings subjected to pressures exceeding 13,0 bar or to steam temperatures exceeding 220°C, and boiler blowdown fittings, are to be made of steel or other approved material.

15.2 Safety valves

15.2.1 Boilers and steam generators are to be fitted with not less than two safety valves, each having a minimum internal diameter of 25 mm, but those having a total heating surface of less than 50 m^2 may have one valve not less than 50 mm diameter. Small oil fired package boilers of the once through coil type used for auxiliary or domestic purposes, where the feed pump capacity limits the output, may have one safety valve not less than 19 mm internal diameter, or two safety valves with internal diameters not less than 16 mm, provided the capacity is in accordance with 15.2.13.

15.2.2 The valves, spindles, springs and compression screws are to be so encased and locked or sealed that the safety valves and pilot valves, after setting to the working pressure, cannot be tampered with or overloaded in service.

15.2.3 Valves are to be so designed that in the event of fracture of springs they cannot lift out of their seats.

15.2.4 Easing gear is to be provided for lifting the safety valves and is to be operable by mechanical means at a safe position from the boiler or engine room platforms.

15.2.5 Safety valves are to be made with working parts having adequate clearances to ensure complete freedom of movement.

15.2.6 Valve seats are to be effectively secured in position. Any adjusting devices which control discharge capacity are to be positively secured so that the adjustment will not be affected when the safety valves are dismantled at surveys.

15.2.7 All the safety valves of each boiler and steam generator may be fitted in one chest, which is to be separate from any other valve chest and is to be connected directly to the shell by a strong and stiff neck, the passage through which is to be of cross-sectional area not less than the aggregate area of the safety valves in the chest in the case of full lift valves, and one half of that area in the case of other valves. For the meaning of aggregate area, *see* 15.2.13.

15.2.8 Each safety valve chest is to be drained by a pipe fitted to the lowest part and led with a continuous fall to the bilge or to a tank, clear of the boilers. No valves or cocks are to be fitted to these drain pipes. The bore of the drain pipes is to be not less than 19 mm.

15.2.9 Safety valves for shell type exhaust gas steaming economisers are to incorporate fail safe features which will ensure operation of the valve even with solid matter deposits on the valve and guide, or features that will prevent the accumulation of solid matter in way of the valve and in the clearance between the valve spindle and guide. Alternatively, if the fitted valves do not incorporate the features described then a bursting disc discharging to a suitable waste steam pipe is to be fitted in addition to the valves. These bursting discs are to function at a pressure not exceeding 1,25 times the economiser approved design pressure and are to have sufficient capacity to prevent damage to the economiser when operating at its design heat input level.

15.2.10 To avoid the accumulation of solid matter deposits on the outlet side of the safety valves and bursting discs required by 15.2.9, the discharge pipes and safety valve/ bursting disc housings are to be fitted with drainage arrangements from the lowest part, directed with continuous fall to a position clear of the economiser where it will not pose a threat to either personnel or machinery. No valves or cocks are to be fitted in the drainage arrangements. The drainage arrangements required by 15.2.8 may be accepted as meeting these requirements where the arrangements comply with this paragraph.

15.2.11 Full particulars of the proposed arrangements are to be submitted for consideration.

15.2.12 Where the receiver is fitted with safety valves to relieve the steam output of the economiser and the economiser cannot be isolated from the receiver the requirements of 15.2.9 may be waived.

15.2.13 The designed discharge capacities of the safety valves on each boiler and steam generator are to be found from the following formulae:

Saturated steam safety valves:

$$E = \frac{AC\,(p + 1{,}03)}{98{,}1}$$

Superheated steam safety valves:

$$E = \frac{AC\,(p + 1{,}03)}{98{,}1}\sqrt{\frac{V_S}{V_H}}$$

where

p = set pressure, in bar gauge

A = for ordinary, high lift or improved high lift safety valves, the aggregate area, in mm^2, of the orifices through the seatings of the valves, neglecting the area of guides and other obstructions

= for full lift safety valves, the net aggregate area, in mm^2, through the seats after deducting the area of the guides or other obstructions when the valves are fully lifted

C = 4,8 for valves of ordinary type having a minimum lift of $\frac{D}{24}$

= 7,2 for valves of high lift type, having a minimum lift of $\frac{D}{16}$

= 9,6 for valves of improved high lift type having a minimum lift of $\frac{D}{12}$

= 19,2 for valves of full lift type having a minimum lift of $\frac{D}{4}$

D = bore of valve seat, in mm

E = the maker's specified peak load evaporation, in kg/hour (including all evaporation from water walls, integral, or steaming economisers and other heating surfaces in direct communication with the boiler)

V_H = specific volume of superheated steam (m^3/kg)

V_S = specific volume of saturated steam (m^3/kg).

15.2.14 When the discharge capacity of a safety valve of approved design has been established by type tests, carried out in the presence of the Surveyors or by an independent authority recognised by LR, on valves representative of the range of sizes and pressures intended for marine application, consideration will be given to the use of a constant higher than C = 19,2, based on 90 per cent of the measured capacity up to a maximum of C = 45 for full lift safety valves.

15.2.15 Pressurised thermal liquid and pressurised hot water heaters are to be provided with a safety relief device. The safety valve is to be designed and constructed in accordance with a relevant National or International Standard acceptable to LR.

15.3 Waste steam pipes

15.3.1 For ordinary, high lift and improved high lift type valves, the cross-sectional area of the waste steam pipe and passages leading to it is to be at least 10 per cent greater than the aggregate area of the safety valves as used in the formulae in 15.2.13. For full lift and other approved valves of high discharge capacity, the cross-sectional area of the waste steam pipe and passages is to be not less than 0,1C times the aggregate valve area.

15.3.2 The cross-sectional area of the main waste steam pipe is to be not less than the combined cross-sectional areas of the branch waste steam pipes leading thereto from the boiler safety valves.

15.3.3 Waste steam pipes are to be led to the atmosphere and are to be adequately supported and provided with suitable expansion joints, bends or other means to relieve the safety valve chests of undue loading.

15.3.4 The scantlings of waste steam pipes and silencers are to be suitable for the maximum pressure to which the pipes may be subjected in service, and in any case not less than 10 bar.

15.3.5 Silencers fitted to waste steam pipes are to be so designed that the clear area through the baffle plates is not less than that required for the pipes.

15.3.6 The safety valves of each exhaust gas heated economiser and exhaust gas heated boiler which may be used as an economiser are to be provided with entirely separate waste steam pipes.

15.3.7 External drains and exhaust steam vents to atmosphere are not to be led to waste steam pipes.

15.3.8 It is recommended that a scale trap and means for cleaning be provided at the base of each waste steam pipe.

15.4 Adjustment and accumulation tests

15.4.1 All safety valves are to be set under steam to a pressure not greater than the approved pressure of the boiler. As a working tolerance the setting is acceptable provided the valves lift at not more than 103 per cent of the approved design pressure. During a test of 15 minutes with the stop valves closed and under full firing conditions the accumulation of pressure is not to exceed 10 per cent of the design pressure. During this test no more feed water is to be supplied than is necessary to maintain a safe working water level.

15.5 Stop valves

15.5.1 One main stop valve is to be fitted to each boiler and secured directly to the shell. There are to be as few auxiliary stop valves as possible so as to avoid piercing the boiler shell more than is absolutely necessary.

15.5.2 Where two or more boilers are connected together:

- Stop valves of self-closing or non-return type are to be fitted.
- Essential services are to be capable of being supplied from at least two boilers.

15.6 Water level indicators

15.6.1 Every boiler designed to contain water at a specified level is to be fitted with at least two means for indicating its water level, at least one of which is to be a direct reading gauge glass. The other means is to be either an additional gauge glass or an approved equivalent device. The required water level indicators are to be independent of each other.

15.6.2 Where a pair of gauge glasses are set at different levels to provide an extended range of water level indication they will only be considered as one water level indicator.

15.6.3 An approved equivalent device for level indication may derive its level input signal from one of the low water level detection systems required by 15.7.1 provided that in the event of a power supply failure to that system an alarm is initiated and the oil fuel supply to the burners, or any other fuel used to fire the boiler, is automatically shut off. The fuel supply shut-off will only be required if the power supply failure results in the direct reading gauge glass being the only functioning water level indicator.

15.6.4 The water gauges are to be readily accessible and placed so that the water level is clearly visible. The lowest visible parts of water gauges are to be situated at the lowest safe working level.

15.6.5 The level of the highest part of the effective heating surfaces, e.g., combustion chamber top of a horizontal boiler and the furnace crown of a vertical boiler, is to be clearly marked in a position adjacent to the glass water gauge.

15.6.6 The cocks of all water gauges are to be operable from positions free from danger in the event of the glass breaking.

15.7 Low water level fuel shut-off and alarm

15.7.1 Every fired boiler designed to contain water at a specified level is to be fitted with two systems of water level detection, which are to be independent of each other, and which will operate an alarm and shut off, automatically, the fuel supply to the burners, or any other fuel used to fire the boiler, when the water level falls to a predetermined low level. These level detectors, in addition, may be used for other functions, e.g., high level alarm, feed pump control, etc.

15.8 Feed check valves

15.8.1 Two feed check and stop valves, connected to separate feed lines, are to be provided for all main and auxiliary boilers which are required for essential services. The feed check and stop valves may be connected to a single standpipe at the shell. In the case of steam/steam generators one feed check valve is acceptable provided steam for essential services is simultaneously available from another source.

15.9 Pressure gauges

15.9.1 Each boiler is to be provided with a separate steam pressure gauge.

15.9.2 The gauges are to be placed where they are easily read.

15.10 Blowdown and scum valves

15.10.1 Each boiler is to be fitted with at least one blowdown valve.

15.10.2 The blowdown valve is to be attached, wherever practicable, direct to the lower part of the boiler. Where it is not practicable to attach the blowdown valve directly, a steel pipe supported from the boiler may be fitted between the boiler and valve.

15.10.3 The blowdown valve and its connections to the sea need not be more than 38 mm, and is to be not less than 19 mm internal diameter. For cylindrical boilers the size of the valve may be generally 0,0085 times the diameter of the boiler.

15.10.4 Blowdown valves and scum valves (where the latter are fitted) of two or more boilers may be connected to one common discharge, but where thus arranged there are to be screw-down non-return valves fitted for each boiler to prevent the possibility of the contents of one boiler passing to another.

15.10.5 For blowdown valves or cocks on the side of the unit and attachments, *see* Ch 13,2.

15.11 Salinometer valve or cock

15.11.1 Each boiler is to be provided with a salinometer valve or cock secured direct to the boiler in a convenient position. The valve or cock is not to be on the water gauge standpipe.

15.12 Additional requirements for shell type exhaust gas steaming economisers

15.12.1 The design and construction of shell type economisers are to pay particular attention to the welding, heat treatment and inspection arrangements at the tube plate connection to the shell.

15.12.2 Every shell type economiser is to be provided with removable lagging at the circumference of the tube end plates to enable ultrasonic examination of the tube plate to shell connection.

15.12.3 Every economiser is to be provided with arrangements for pre-heating and de-aeration, and addition of water treatment or combination thereof, to control the quality of feed water to within the manufacturer's recommendations.

15.12.4 The manufacturer is to provide operating instructions for each economiser which is to include reference to:

- Feed water treatment and sampling arrangements.
- Operating temperatures – exhaust gas and feed water temperatures.
- Operating pressure.
- Inspection and cleaning procedures.
- Records of maintenance and inspection.
- The need to maintain adequate water flow through the economiser under all operating conditions.
- Periodical operational checks of the safety devices to be carried out by the operating personnel and to be documented accordingly.
- Procedures for using the exhaust gas economiser in the dry condition.
- Procedures for maintenance and overhaul of safety valves.
- Emergency operating procedures.

■ *Section 16* Mountings and fittings for water tube boilers

16.1 General

16.1.1 Mountings and fittings not mentioned in this Section are to be in accordance with the requirements in Section 15.

16.2 Safety valves

16.2.1 Water tube boilers are to be fitted with not less than two safety valves of area and design in general accordance with the requirements of 15.2.

16.2.2 Each saturated steam drum and each superheater are to be provided with at least one safety valve.

16.2.3 Where the superheater forms an integral part of the boiler, the relieving capacity of the superheater safety valve(s), based on the reduced pressure at the superheater outlet, may be included as part of the total relieving capacity required for the boiler. As some National Authorities limit the proportion of the superheater safety valve relieving capacity which may be credited towards the total capacity for the boiler, Builders should give attention to any relevant Statutory Requirements of the National Authority of the country in which the unit is to be registered.

16.2.4 The boiler and superheater valves are to be so disposed and proportioned between saturated steam drum and superheater outlet that the superheater will be protected from overheating under all service conditions, including an emergency stop of the unit at full power.

16.2.5 Where it is proposed to fit full bore safety valves operated by independent pilot valves, the arrangements are to be submitted for consideration. The pipes connecting pilot valves and main valves are to be of ample bore and wall thickness to minimise the possibility of obstruction and damage.

16.2.6 Where it is impracticable to attach safety valves directly to the superheater, the valves are to be located as near as possible thereto and fitted to a branch piece connected to the superheater outlet pipe.

16.2.7 In high temperature installations the drains from safety valves are to be led to a tank or other place where high temperature steam can be safely discharged.

16.3 Safety valve settings

16.3.1 All boiler and superheater safety valves are to be set under steam to their respective working pressures, which are not to be greater than the approved design pressure of the boiler. As a working tolerance the setting is acceptable provided the valves lift at not more than 103 per cent of the approved pressure.

16.3.2 In the setting of superheater safety valves, allowance is to be made for the pressure drop through the superheater so that under discharge conditions the pressure in the boiler will not exceed the approved boiler pressure.

16.3.3 In no case is the superheater safety valve setting to exceed by more than three per cent the pressure for which the steam piping is approved.

16.4 Waste steam pipes

16.4.1 The waste steam pipe and passages leading to it from the safety valves are to be in general accordance with the requirements of 15.3.

16.4.2 In installations operating with a high degree of superheat, consideration is to be given to the high temperatures which waste steam pipes, silencers and surrounding spaces will attain when the superheater safety valves are blowing during accumulation tests and in service, adequate protection against heat effects is to be provided to the Surveyor's satisfaction.

16.4.3 Waste steam pipes are to be led well clear of electric cables and any parts or structures sensitive to heat or likely to distort; the pipes are to be insulated where necessary. In these installations each boiler should have a separate waste steam pipe system to atmosphere, with supporting and expansion arrangements such that no direct loading is imposed on the safety valve chests.

16.5 Accumulation tests

16.5.1 Tests for accumulation of pressure are to be carried out with the stop valve closed and under full firing conditions for a period not exceeding seven minutes. The accumulation is not to exceed 10 per cent of the design pressure.

16.5.2 Where accumulation tests might endanger the superheaters, consideration will be given in cases of fired boilers to the omission of these tests, provided that application is made when the boiler plan and sizes of safety valves are submitted for approval, and that the safety valves are of an approved type for which the capacity has been established by test in the presence of the Surveyors or an approved independent authority, or for which LR is satisfied, by long experience of accumulation tests, that the capacity is adequate. When it is agreed to waive accumulation tests, it will be required that the valve makers provide a certificate for each safety valve, stating its rated capacity at the approved working conditions of the boilers and that the boiler makers provide a certificate for each boiler stating its maximum evaporation.

16.5.3 The safety valves are to be found satisfactory in operation under working conditions during the trials of the machinery on board the unit.

16.6 Water level indicators

16.6.1 Every boiler designed to contain water at a specified level is to be fitted with at least two means for indicating its water level, at least one of which is to be a direct reading gauge glass. The other means is to be either an additional gauge glass or an approved equivalent device. The required water level indicators are to be independent of each other.

16.6.2 Where a pair of gauge glasses are set at different levels to provide an extended range of water level indication they will only be considered as one water level indicator.

16.6.3 An approved equivalent device for level indication may derive its level input signal from one of the low water level detection systems required by 16.7.1 provided that, in the event of a power supply failure to that system, an alarm is initiated and the oil fuel supply to the burners, or any other fuel used to fire the boiler, is automatically shut off. The fuel supply shut-off will only be required if the power supply failure results in the direct reading gauge glass being the only functioning water level indicator.

16.6.4 Where a steam and water drum exceeding 4 m in length is fitted athwartships, two glass water gauges are to be fitted in suitable positions, one near each end of the drum.

16.6.5 The position of the glass water gauge of boilers in which the tubes are entirely drowned when cold is to be such that water is just showing in the glass when the water level in the steam drum is just above the top of the uppermost tubes when the boiler is cold.

16.6.6 In boilers, the tubes of which are not entirely drowned when cold, the glass water gauges are to be placed, to the Surveyor's satisfaction, in the positions which have been found by experience to indicate satisfactorily that the water content is sufficient for safety when the boiler is worked under all service conditions.

16.7 Low water level fuel shut-off and alarm

16.7.1 Every fired boiler designed to contain water at a specified level is to be fitted with two systems of water level detection which are to be independent of each other, and which will operate an alarm and shut off automatically the fuel supply to the burners when the water level falls to a predetermined low level. These level detectors may be used for other functions, e.g., high level alarm, feed pump control, etc.

16.7.2 Any proposals to depart from these requirements in the case of small auxiliary boilers will be the subject of special consideration.

16.7.3 *See* Pt 6, Ch 1 for requirements for control, alarm and safety systems, and additional requirements for unattended operation.

16.8 Feed check valves and water level regulators

16.8.1 Two feed check and stop valves, connected to separate feed lines, are to be provided for each boiler and are to be attached, wherever practicable, direct to the boiler or to an economiser which forms an integral part of the boiler.

16.8.2 Where the arrangements necessitate the use of a common inlet pipe on the economiser for both main and auxiliary feed systems, this pipe is to be as short as practicable, and the arrangements of check valves are to be such that either feed line can be effectively isolated without interruption of the feed water supply to the boiler.

16.8.3 At least one of the feed water systems is to be fitted with an approved feed water regulator whereby the water level in the boilers is controlled automatically. *See* Ch 14,6 for arrangements and details of boiler feed systems.

16.8.4 The feed check valves are to be fitted with efficient gearing, whereby they can be satisfactorily worked from the stokehold floor, or other convenient position.

16.8.5 Standpipes on boilers, for feed inlets, are to be designed with an internal pipe to prevent direct contact between the feed pipe and the boiler shell or end plates with the object of minimising thermal stresses in these plates. Similar arrangements are to be provided for desuperheater and other connections where significant temperature differences occur in service.

■ *Section 17* Hydraulic tests

17.1 General

17.1.1 Boilers and pressure vessels, together with their components are to withstand the following hydraulic tests without any sign of weakness or defect.

17.1.2 Having regard to the variation in the types and design of boilers, the hydraulic test may be carried out by either of the methods indicated below:

(a) boilers are to be tested on completion to a pressure 1,5 times the approved design pressure, or

(b) where construction permits, all components of the boiler are to be tested on completion of the work including heat treatment to 1,5 times the design pressure. In the case of components such as drums or headers, which are to be drilled for tube holes, the test may be before drilling the tube holes, but is to be after the attachment of standpipes, stubs and similar fittings and also after heat treatment has been carried out. Where all the components have been tested as above, each completed boiler after assembly is to be tested to 1,25 times the design pressure.

17.2 Mountings

17.2.1 All boiler mountings are to be subjected to a hydraulic test of twice the approved design pressure with the exception of feed check valves and other mountings connected to the main feed system which are to be tested to 2,5 times the approved boiler design pressure, or twice the maximum pressure which can be developed in the feed line in normal service, whichever is greater.

■ *Section 18* Boiler controls

18.1 Control

18.1.1 When main, auxiliary and other boilers are fitted with automatic or remote controls so that under normal operating conditions they do not require any manual intervention by the operators, they are to be provided with the alarms and safety arrangements as required by 18.2 as appropriate. Alternative arrangements which provide equivalent safeguards will be considered.

18.1.2 The design of the alarm control and safety systems is to comply with the requirements of Pt 6, Ch 1,2.

18.2 Alarms and safeguards

18.2.1 Alarms and safeguards are to be provided as indicated in 18.2.2 and Table 1.3.4 in Pt 6, Ch 1 of the Rules for Ships.

18.2.2 The following boiler services are to be fitted with automatic controls so as to maintain steady state conditions throughout the normal operating range of the boiler:

(a) Combustion system.
(b) Oil fuel supply temperature or viscosity, heavy oil only.
(c) Boiler drum water level.
(d) De-aerator water level where applicable.
(e) Superheated steam pressure where applicable.
(f) Superheated steam temperature where applicable.
(g) De-superheated steam pressure where applicable.
(h) De-superheated steam temperature where applicable.

Section 1 General requirements

1.1 Application

1.1.1 The requirements of this Chapter are applicable to fusion welded pressure vessels and plate heat exchangers, intended for marine purposes but not included in Chapter 10. The equations in this Chapter may be used for determining the thickness of seamless pressure vessels using a joint factor of 1,0. Seamless pressure vessels are to be manufactured and tested in accordance with the requirements of Chapter 5 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials). For the construction and design of pressure vessels and plate heat exchangers for liquefied gas or chemical cargo applications, *see* the *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquefied Gases in Bulk* (hereinafter referred to as the Rules for Ships for Liquefied Gases) or the *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquid Chemicals in Bulk* (hereinafter referred to as the Rules for Ships for Liquid Chemicals) as applicable.

1.1.2 Where the required design criteria for pressure vessels are not indicated within this Chapter, the relevant Sections of Chapter 10 are applicable.

1.1.3 Seamless pressure vessels are to be manufactured in accordance with the requirements of the Rules for Materials where applicable.

1.2 Definition of symbols

1.2.1 The symbols used in the various formulae in Sections 2 to 7 inclusive, unless otherwise stated, are defined as follows, and are applicable to the specific part of the pressure vessel under consideration:

d = diameter of hole, or opening, in mm
p = design pressure, *see* 1.3, in bar
r_i = inside knuckle radius, in mm
r_o = outside knuckle radius, in mm
s = pitch, in mm
t = minimum thickness, in mm
D_i = inside diameter, in mm
D_o = outside diameter, in mm
J = joint factor applicable to welded seams, *see* 1.9, or ligament efficiency between tube holes (expressed as a fraction, *see* Ch 10,2.2)
R_i = inside radius, in mm
R_o = outside radius, in mm
T = design temperature, in °C
σ = allowable stress, *see* 1.8, in N/mm^2.

1.2.2 Where reference is made to calculated or actual plate thickness for the derivation of other values, these thicknesses are to be minus the standard Rule corrosion allowance of 0,75 mm, if not so stated.

1.3 Design pressure

1.3.1 The design pressure is the maximum permissible working pressure, and is to be not less than the highest set pressure of any relief valve.

1.3.2 Calculations made to determine the scantlings of the pressure parts are to be based on the design pressure, adjusted where necessary to take account of pressure variations corresponding to the most severe operational conditions.

1.3.3 It is desirable that there should be a margin between the normal pressure at which the pressure vessel operates and the lowest pressure at which any relief valve is set to lift, to prevent unnecessary lifting of the relief valve.

1.4 Metal temperature

1.4.1 The metal temperature, T, used to evaluate the allowable stress, σ, is to be taken as the actual metal temperature expected under operating conditions for the pressure part concerned, and is to be stated by the manufacturer when plans of the pressure parts are submitted for consideration.

1.4.2 The design temperature, T, for calculation purposes is to be not less than 50°C.

1.5 Classification of fusion welded pressure vessels

1.5.1 For Rule purposes, pressure vessels are graded as Class 1 where the shell thickness exceeds 38 mm.

1.5.2 For Rule purposes, pressure vessels are graded as Class 2/1 and Class 2/2 if they comply with the following conditions:

(a) where the design pressure exceeds 17,2 bar, or
(b) where the metal temperature exceeds 150°C, or
(c) where the design pressure, in bar, multiplied by the actual thickness of the shell, in mm, exceeds 157, or
(d) where the shell thickness does not exceed 38 mm.

1.5.3 For Rule purposes, Class 3 pressure vessels are to have a maximum shell thickness of 16 mm, and are pressure vessels not included in Classes 1, 2/1 or 2/2.

1.5.4 Pressure vessels which are constructed in accordance with Classes 2/1, 2/2 or 3 standards (as indicated above) will, if manufactured in accordance with the requirements of superior Class, be approved with the scantlings appropriate to that Class.

1.5.5 Pressure vessels which only have circumferential fusion welded seams will be considered as seamless with no Class being assigned. Preliminary weld procedure tests and non-destructive examination for the circumferential seam welds should be carried out for the equivalent Class as determined by 1.5.1, 1.5.2 and 1.5.3.

1.5.6 In special circumstances relating to service conditions, materials, operating temperature, the carriage of dangerous gases and liquids, etc., it may be required that certain pressure vessels be manufactured in accordance with the requirements of a superior Class.

1.5.7 Details of heat treatment, non-destructive examination and routine tests (where required) are given in Chapter 13 of the Rules for Materials.

1.5.8 Hydraulic testing is required for all Classes of pressure vessels.

1.5.9 For a full definition of Classes of pressure vessels relating to boilers and associated pressure vessels, *see* Ch 10,1.

1.6 Plans

1.6.1 Plans of pressure vessels are to be submitted in triplicate for consideration where all the conditions in (a) or (b) are satisfied:

(a) The vessel contains vapours or gases, e.g., air receivers, hydrophore or similar vessels and gaseous CO_2 vessels for fire-fighting, and
  $pV > 600$
  $p > 1$
  $V > 100$
  V = volume (litres) of gas or vapour space
(b) The vessel contains liquefied gases, for fire-fighting or flammable liquids, and
  $p > 7$
  $V > 100$
  V = volume (litres)
  p is as defined in 1.2.1.

1.6.2 Plans of full constructional features of the vessel and dimensional details of the weld preparations for longitudinal and circumferential seams and attachments, together with particulars of the welding consumables and of the mechanical properties of the materials, are to be submitted before construction is commenced.

1.7 Materials

1.7.1 Materials used in the construction of Class 1, 2/1 and 2/2 pressure vessels are to be manufactured, tested and certified in accordance with the requirements of the Rules for Materials. Materials used in the construction of Class 3 pressure vessels may be in accordance with the requirements of an acceptable national or international specification. The manufacturer's certificate will be accepted in lieu of Lloyd's Register's (hereinafter referred to as LR) material certificate for such materials.

1.7.2 The specified minimum tensile strength of carbon and carbon-manganese steel plates, pipes, forgings and castings is to be within the general limits of 340 to 520 N/mm^2.

1.7.3 The specified minimum tensile strength of low alloy steel plates, pipes, forgings and castings is to be within the general limits of 400 to 500 N/mm^2, and pressure vessels made in these steels are to be either seamless or Class 1 fusion welded.

1.7.4 Where it is proposed to use materials other than those specified in the Rules for Materials, details of the chemical compositions, heat treatment and mechanical properties are to be submitted for approval. In such cases, the values of the mechanical properties used for deriving the allowable stress are to be subject to agreement by LR.

1.8 Allowable stress

1.8.1 The term 'allowable stress', σ, is the stress to be used in the formulae for the calculation of scantlings of pressure parts.

1.8.2 The allowable stress, σ, is to be the lowest of the following values:

$$\sigma = \frac{E_t}{1,5} \qquad \sigma = \frac{R_{20}}{2,7} \qquad \sigma = \frac{S_R}{1,5}$$

where

E_t = specified minimum lower yield stress or 0,2 per cent proof stress at temperature, T, for carbon and carbon-manganese steels. In the case of austenitic steels, the 1,0 per cent proof stress at temperature, T, is to be used
R_{20} = specified minimum tensile strength at room temperature
S_R = average stress to produce rupture in 100 000 hours at temperature, T
T = metal temperature, *see* 1.4.

1.8.3 The allowable stress for steel castings is to be taken as 80 per cent of the value determined by the method indicated in 1.8.2 using the appropriate values for cast steel.

1.8.4 Where steel castings, which have been tested in accordance with the Rules for Materials are also subjected to non-destructive tests, consideration will be given to increasing the allowable stress using a factor up to 90 per cent in lieu of the 80 per cent referred to in 1.8.3. Particulars of the non-destructive test proposals are to be submitted for consideration.

1.9 Joint factors

1.9.1 The following joint factors are to be used in the equations in Sections 2 to 6, where applicable. Fusion welded pressure parts are to be made in accordance with Chapter 17.

Class of pressure vessel	Joint factor
Class 1	1,0
Class 2/1	0,85
Class 2/2	0,75
Class 3	0,60

1.9.2 The longitudinal joints for all Classes of vessels are to be butt joints. Circumferential joints for Class 1 vessels are also to be butt welds. Circumferential joints for Classes 2/1, 2/2 and 3 vessels should also be butt joints with the following exceptions:

(a) Circumferential joints for Classes 2/1, 2/2 and 3 vessels may be of the joggle type provided neither plate at the joints exceeds 16 mm thickness.
(b) Circumferential joints for Class 3 vessels may be of the lap type provided neither plate at the joint exceeds 16 mm thickness nor the internal diameter of the vessel exceeds 610 mm.

For typical acceptable methods of attaching flat ends, *see* Fig. 10.8.2 and Fig. 10.9.1 in Chapter 10.
For typical acceptable methods of attaching dished ends, *see* Fig 11.8.1.

1.9.3 Where a pressure vessel is to be made of alloy steel, particulars of the welding consumables to be used, including typical mechanical properties and chemical composition of the deposited weld metal, are to be submitted for approval.

1.10 Pressure parts of irregular shape

1.10.1 Where pressure parts are of such irregular shape that it is impracticable to design their scantlings by the application of the formulae in Sections 2 to 7, the suitability of their construction is to be determined by hydraulic proof test of a prototype or by an agreed alternative method.

1.11 Adverse working conditions

1.11.1 Where working conditions are adverse, special consideration may require to be given to increasing the scantlings derived from the formulae. In this connection, where necessary, account should also be taken of any excess of loading resulting from:

(a) impact loads, including rapidly fluctuating pressures,
(b) weight of the vessel and normal contents under operating and test conditions,
(c) superimposed loads, such as other pressure vessels, operating equipment, insulation, corrosion-resistant or erosion-resistant linings and piping,
(d) reactions of supporting lugs, rings, saddles or other types of supports, or
(e) the effect of temperature gradients on maximum stress.

■ *Section 2*
Cylindrical shells and drums subject to internal pressure

2.1 Minimum thickness

2.1.1 The minimum thickness, t, of a cylindrical shell is to be determined by the following formula:

$$t = \frac{p\,R_i}{10\sigma\,J - 0{,}5p} + 0{,}75 \text{ mm}$$

where

t, p, R_i and σ are as defined in 1.2
J = the joint factor of the longitudinal joints (expressed as a fraction). *See* 1.9 in the case of seamless shells clear of openings J = 1,0.

2.1.2 The formula in 2.1.1 is applicable only where the resulting thickness does not exceed half the internal radius, i.e., where R_o is not greater than $1{,}5R_i$.

2.1.3 Irrespective of the thickness determined by the formula in 2.1.1, t is to be not less than $3 + \frac{D_i}{1500}$ mm, where D_i is as defined in 1.2. The minimum thickness permitted for vessels manufactured in corrosion resistant steels will be the subject of special consideration.

■ *Cross-references*

For efficiency of ligaments between tube holes, *see* Ch 10,2.2.
For compensating effect of tube stubs, *see* Ch 10,2.3.
For unreinforced openings, *see* Ch 10,2.4.
For reinforced openings, *see* Ch 10,2.5.

Section 3
Spherical shells subject to internal pressure

3.1 Minimum thickness

3.1.1 The minimum thickness, t, of a spherical shell is to be determined by the following formula:

$$t = \frac{p\,R_i}{20\sigma\,J - 0{,}5p} + 0{,}75 \quad \text{mm}$$

where
t, p, R_i, σ and J are as defined in 1.2.

3.1.2 The formula in 3.1.1 is applicable only where the resulting thickness does not exceed half the internal radius.

3.1.3 Irrespective of the thickness determined by the formula in 3.1.1, t is to be not less than $3 + \frac{D_i}{1500}$ mm, where D_i is as defined in 1.2. The minimum thickness permitted for vessels manufactured in corrosion resistant steels will be the subject of special consideration.

3.1.4 Openings in spherical shells requiring compensation are to comply, in general, with Ch 10,2.5, using the calculated and actual thickness of the spherical shell as applicable.

Section 4
Dished ends subject to internal pressure

4.1 Minimum thickness

4.1.1 The thickness, t, of semi-ellipsoidal and hemispherical unstayed ends and the knuckle section of torispherical ends, dished from plate, having pressure on the concave side and satisfying the conditions listed below, is to be determined by the following formula:

$$t = \frac{p\,D_o\,K}{20\sigma\,J} + 0{,}75 \quad \text{mm}$$

where
t, p, D_o, σ and J are as defined in 1.2
K = a shape factor, *see* Ch 10,4.2 and Fig. 10.4.1.

4.1.2 For semi-ellipsoidal ends:
the external height, $H \geq 0{,}18D_o$
where
D_o = the external diameter of the parallel portion of the end, in mm.

4.1.3 For torispherical ends:
the internal radius, $R_i \leq D_o$
the internal knuckle radius, $r_i \geq 0{,}1D_o$
the internal knuckle radius, $r_i \geq 3t$
the external height, $H \geq 0{,}18D_o$, and is determined as follows:

$$H = R_o - \sqrt{(R_o - 0{,}5D_o)(R_o + 0{,}5D_o - 2r_o)}$$

4.1.4 In addition to the formula in 4.1.1 the thickness, t, of a torispherical head, made from more than one plate, in the crown section, is to be not less than that determined by the following formula:

$$t = \frac{p\,R_i}{20\sigma\,J - 0{,}5p} + 0{,}75 \quad \text{mm}$$

where
t, p, R_i, σ, and J are as defined in 1.2.

4.1.5 The thickness required by 4.1.1 for the knuckle section of a torispherical head is to extend past the common tangent point of the knuckle and crown radii into the crown section for a distance not less than $0{,}5\sqrt{R_i\,t}$ mm, before reducing to the crown thickness permitted by 4.1.4
where
t = the required thickness from 4.1.1.

4.1.6 In all cases, H is to be measured from the commencement of curvature, shown in Fig. 10.4.2, in Chapter 10.

4.1.7 The minimum thickness of the head, t, is in no case to be less than $3 + \frac{D_i}{1500}$ mm, where D_i is as defined in 1.2. The minimum thickness permitted for vessels manufactured in corrosion resistant steels will be the subject of special consideration.

4.1.8 For ends which are butt welded to the drum shell, *see* 1.9, the thickness of the edge of the flange for connection to the shell is to be not less than the thickness of an unpierced seamless or welded shell, whichever is applicable, of the same diameter and material and determined by 2.1.

Cross-references

For shape factors for dished ends, *see* Ch 10,4.2.
For dished ends with unreinforced openings, *see* Ch 10,4.3.
For flanged openings in dished ends, *see* Ch 10,4.4.
For location of unreinforced and flanged openings in dished ends, *see* Ch 10,4.5.
For dished ends with reinforced openings, *see* Ch 10,4.6 and 4.7.

Section 5
Dished ends for Class 3 pressure vessels

5.1 Minimum thickness

5.1.1 As an alternative to the formula in 4.1.1, for Class 3 vessels only, the minimum thickness, *t*, of a torispherical unstayed end dished from plate and having pressure on the concave or convex side is to be determined by the following formula:

$$t = \frac{p\,R_i}{CS}$$

where

t, p, and R_i are as defined in 1.2

C = 2,57 for ends concave to pressure

= 1,65 for ends convex to pressure

S = specified minimum tensile strength of plate, in N/mm^2, which should be not less than 410 N/mm^2.

5.1.2 The inside radius of curvature, R_i, of the end plate is to be not greater than the external diameter of the cylinder to which it is attached.

5.1.3 The inside knuckle radius, r_i, of the arc joining the cylindrical flange to the spherical surface of the end is to be not less than four times the thickness of the end plate, and in no case less than 65 mm.

5.1.4 Ends convex to pressure are not to be used for vessels exceeding 610 mm internal diameter.

5.1.5 Where the end is provided with a flanged manhole, the thickness of the end, in mm, determined by 5.1.1, is to be increased by 3 mm, and the total depth, *H*, of the manhole flange, measured from the outer surface of the plate on the minor axis, is to be not less than:

$$H = \sqrt{t_1\,W}$$

where

t_1 = required thickness of the plate, in mm

H = depth of flange, in mm

W = minor axis of the manhole, in mm.

Section 6
Conical ends subject to internal pressure

6.1 General

6.1.1 Conical ends and conical reducing sections, as shown in Fig. 10.5.1 in Chapter 10, are to be designed in accordance with the equations given in 6.2.

6.1.2 Connections between cylindrical shell and conical sections and ends should preferably be by means of a knuckle transition radius. Typical permitted details are shown in Fig. 10.5.1 in Chapter 10. Alternatively, conical sections and ends may be butt welded to cylinders without a knuckle radius when the change in angle of slope, ψ, between the two sections under consideration does not exceed 30°.

6.1.3 Conical ends may be constructed of several ring sections of decreasing thickness as determined by the corresponding decreasing diameter.

6.2 Minimum thickness

6.2.1 The minimum thickness, *t*, of the cylinder, knuckle and conical section at the junction and within the distance *L* from the junction is to be determined by the following formula:

$$t = \frac{p\,D_o\,K}{20\sigma\,J} + 0{,}75 \quad \text{mm}$$

where

t, p, σ and J are as defined in 1.2

D_o = outside diameter, in mm of the conical section or end, *see* Fig. 10.5.1 in Chapter 10

K = a factor, taking into account the stress in the knuckle, *see* Table 10.5.1 in Chapter 10.

6.2.2 If the distance of a circumferential seam from the knuckle or junction is not less than *L*, then *J* is to be taken as 1,0; otherwise *J* is to be taken as the weld joint factor appropriate to the circumferential seam,

where

r_i = inside radius of transition knuckle, in mm, which is to be taken as $0{,}01D_c$ in the case of conical sections without knuckle transition

L = distance, in mm, from knuckle or junction within which meridional stresses determine the required thickness, *see* Fig. 10.5.1 in Chapter 10

$$= 0{,}5\sqrt{\frac{D_o\,t}{\cos\psi}}$$

ψ = difference between angle of slope of two adjoining conical sections, *see* Fig. 10.5.1 in Chapter 10.

6.2.3 The minimum thickness, *t*, of those parts of conical sections not less than a distance *L* from the junction with a cylinder or other conical section, is to be determined by the following formula:

$$t = \frac{p\,D_c}{20\sigma\,J - p}\;\frac{1}{\cos\alpha} + 0{,}75 \quad \text{mm}$$

where

D_c = inside diameter, in mm, of conical section or end at the position under consideration, *see* Fig. 10.5.1 in Chapter 10

$\alpha, \alpha_1, \alpha_2$ = angle of slope of conical section (at the point under consideration) to the vessel axis, *see* Fig. 10.5.1 in Chapter 10.

6.2.4 The thickness of conical sections having an angle of inclination to the vessel axis of more than 75° is to be determined as for a flat plate.

Section 7
Standpipes and branches

7.1 Minimum thickness

7.1.1 The minimum wall thickness, t, of standpipes and branches is to be not less than the greater of the two values determined by the following formulae, making such additions as may be necessary on account of bending, static loads and vibrations:

$$t = \frac{p\,D_o}{20\sigma + p} + 0{,}75 \text{ mm, or}$$

$$t = 0{,}015D_o + 3{,}2 \text{ mm}$$

where
t, p, D_o and σ are defined in 1.2.
If the second formula applies, the thickness need only be maintained for a length, L, from the outside surface of the vessel, but need not extend past the first connection, butt weld or flange, where:

$$L = 3{,}5\sqrt{D_o\,t} \text{ mm}$$

7.1.2 In no case need the wall thickness exceed the minimum shell thickness as required by 2.1, 3.1 or 4.1 as applicable.

Section 8
Construction

8.1 Access arrangements

8.1.1 Pressure vessels are to be so made that the internal surfaces may be examined. Wherever practicable, the openings for this purpose are to be sufficiently large for access and for cleaning the inner surfaces. Requirements for welding and NDE are given in chapters 12 and 13 of the Rules for Materials.

8.1.2 Manholes in cylindrical shells should preferably have their shorter axes arranged longitudinally.

8.1.3 Doors for manholes and sightholes are to be formed from steel plate or of other approved construction, and all jointing surfaces are to be machined.

8.1.4 Doors of the internal type are to be provided with spigots which have a clearance of not more than 1,5 mm all round, i.e., the axes of the opening are not to exceed those of the door by more than 3 mm. The width of the manhole gasket seat is not to be less than 16 mm.

8.1.5 Doors of the internal type for openings not larger than 230 x 180 mm need be fitted with only one stud, which may be forged integral with the door. Doors for openings larger than 230 mm x 180 mm are to be fitted with two studs or bolts. The strength of the attachment to the door is not to be less than the strength of the stud or bolt.

8.1.6 The crossbars or dogs for doors are to be of steel.

8.1.7 External circular flat cover plates are to be in accordance with a Recognised Standard.

8.2 Torispherical and semi-ellipsoidal ends

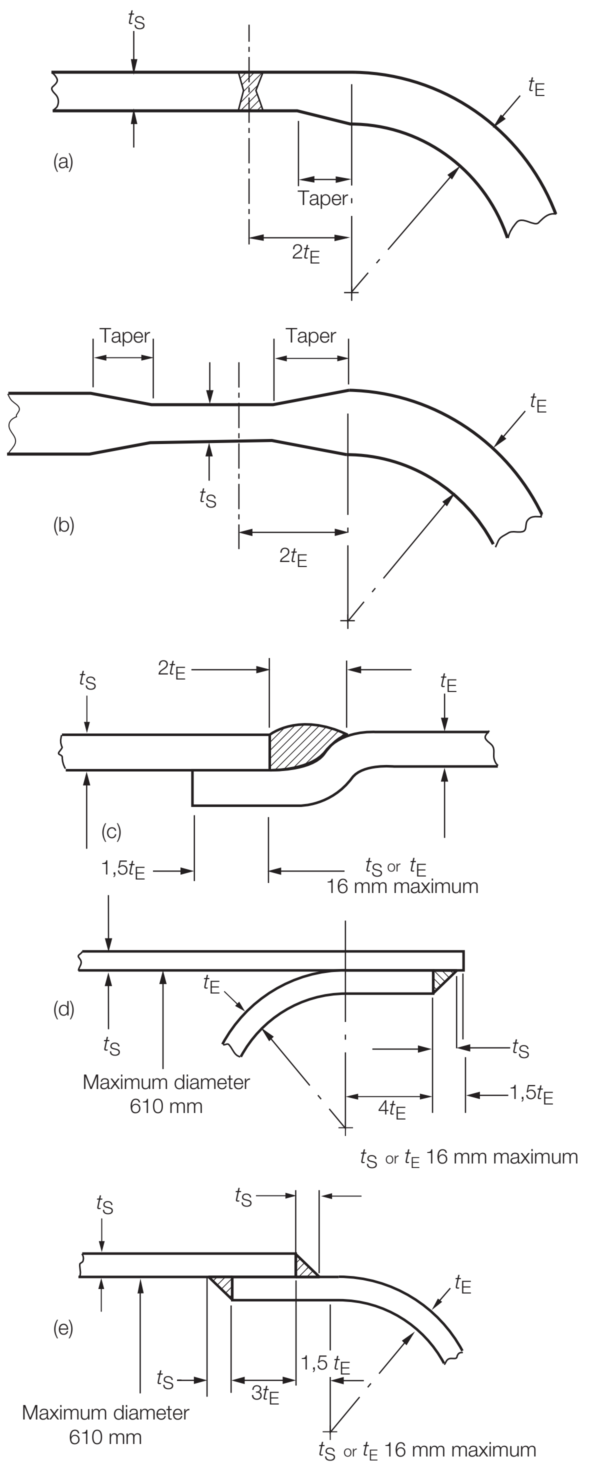
8.2.1 For typical acceptance types of attachment for dished ends to cylindrical shells, *see* Fig. 11.8.1. Types (d) and (e) are to be made a tight fit in the cylindrical shell.

8.2.2 Where the difference in thickness is the same throughout the circumference, the thicker plate is to be reduced in thickness by machining to a taper for a distance not less than four times the offset, so that the two plates are of equal thickness at the position of the circumferential weld. A parallel portion may be provided between the end of the taper and the weld edge preparation; alternatively, if so desired, the width of the weld may be included as part of the smooth taper of the thicker plate.

8.2.3 The thickness of the plates at the position of the circumferential weld is to be not less than that of an unpierced cylindrical shell of seamless or welded construction, whichever is applicable, of the same diameter and material, *see* 2.1.

Cross-references

For hemispherical ends, *see* Ch 10,14.3.
For openings in flat ends, *see* Ch 10,8.4.
For unstayed circular flat end plates, *see* Ch 10,8.4.
For welded-on flanges, butt joints and fabricated branch pieces, *see* Ch 10,14.4.
For welded attachments to pressure vessels, *see* Ch 10,14.5.



Type of end attachment	Acceptable for
(a) and (b)	All classes
(c)	2/1, 2/2 and 3
(d) and (e)	Class 3 only

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Fig. 11.8.1
Typical attachment of dished ends to cylindrical shell

■ *Section 9*
Mountings and fittings

9.1 General

9.1.1 Each pressure vessel or system is to be fitted with a stop valve situated as close as possible to the shell.

9.1.2 Adequate arrangements are to be provided to prevent over-pressure of any part of a pressure vessel which can be isolated. Pressure gauges are to be fitted in positions where they can be easily read.

9.1.3 Adequate arrangements are to be provided for draining and venting the separate parts of each pressure vessel.

9.2 Receivers containing pressurised gases

9.2.1 Each air receiver is to be fitted with a drain arrangement at its lowest part, permitting oil and water to be blown out.

9.2.2 Each receiver which can be isolated from a relief valve is to be provided with a suitable fusible plug to discharge the contents in case of fire. The melting point of the fusible plug is to be approximately 150°C, *see also* 9.2.3 and 9.2.4.

9.2.3 Where a fixed system utilising fire-extinguishing gas is fitted, to protect a machinery space containing an air receiver(s), fitted with a fusible plug, it is recommended that the discharge from the fusible plug be piped to the open deck.

9.2.4 Receivers used for the storage of air for the control of remotely operated valves are to be fitted with relief valves and not fusible plugs.

■ *Cross-references*

For starting air pipe systems and safety fittings, *see* Ch 2,7.
For mountings for liquefied gas vessels, *see* the Rules for Ships for Liquefied Gases.

■ *Section 10*
Hydraulic tests

10.1 General

10.1.1 Pressure vessels covered by this Chapter are to be tested on completion to a pressure, p_T, determined by the following formula, without showing signs of weakness or defect:

$$p_T = 1{,}3 \frac{\sigma_{50}}{\sigma_T} \frac{t}{(t - 0{,}75)} p$$

but in no case is to exceed

$$= 1{,}5 \frac{t}{(t - 0{,}75)} p$$

where

p = design pressure, in bar
p_T = test pressure, in bar
t = nominal thickness of shell as indicated on the plan, in mm
σ_T = allowable stress at design temperature, in N/mm^2
σ_{50} = allowable stress at 50°C, in N/mm^2.

10.2 Mountings

10.2.1 Mountings are to be subjected to a hydraulic test of twice the approved design pressure.

■ *Section 11*
Plate heat exchangers

11.1 General

11.1.1 Plate heat exchangers are to be classed as follows.
Class 2 where either of the following conditions apply:
(a) the maximum metal design temperature is 150°C or greater, or
(b) design pressure is 17,2 bar or greater.
Class 3 in all other cases.

11.1.2 Where the design temperature is equal to or lower than minus 10°C, a higher class is to apply.

Section

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter apply to the design and construction of piping systems, including pipe fittings forming parts of such systems.

1.1.2 The materials used for pipes, valves and fittings are to be suitable for the medium and the service for which the piping is intended.

1.1.3 The piping systems for LPG and LNG carriers, gas fuelled units and classed refrigeration systems are to comply with the relevant Sections of this Chapter where applicable and the additional requirements in Section 9 as well as the requirements contained in the *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquefied Gases in Bulk* (hereinafter referred to as the Rules for Ships for Liquefied Gases).

1.2 Design symbols

1.2.1 The symbols used in this Chapter are defined as follows:

a = percentage negative manufacturing tolerance on thickness
c = corrosion allowance, in mm
d = inside diameter of pipe, in mm, *see* 1.2.3
e = weld efficiency factor, *see* 1.2.4
p = design pressure, in bar (kgf/cm^2), *see* 1.3
p_t = hydraulic test pressure, in bar (kgf/cm^2)
t = the minimum thickness of a straight pipe, in mm, including corrosion allowance and negative tolerance, where applicable
t_b = the minimum thickness of a straight pipe to be used for a pipe bend, in mm, including bending allowance, corrosion allowance and negative tolerance, where applicable
D = outside diameter of pipe, in mm, *see* 1.2.2
R = radius of curvature of a pipe bend at the centreline of the pipe, in mm
T = design temperature, in °C, *see* 1.4
σ = maximum permissible design stress, in N/mm^2 (kgf/cm^2).

1.2.2 The outside diameter, D, is subject to manufacturing tolerances, but these are not to be used in the evaluation of formulae.

1.2.3 The inside diameter, d, is not to be confused with nominal size, which is an accepted designation associated with outside diameters of standard rolling sizes.

1.2.4 The weld efficiency factor, e, is to be taken as 1 for seamless and electric resistance and induction welded steel pipes. Where other methods of pipe manufacture are proposed, the value of e will be specially considered.

1.3 Design pressure

1.3.1 The design pressure, p, is the maximum permissible working pressure and is to be not less than the highest set pressure of the safety valve or relief valve.

1.3.2 In water tube boiler installations, the design pressure for steam piping between the boiler and integral superheater outlet is to be taken as the design pressure of the boiler, i.e. not less than the highest set pressure of any safety valve on the boiler drum. For piping leading from the superheater outlet, the design pressure is to be taken as the highest set pressure of the superheater safety valves.

1.3.3 The design pressure of feed piping and other piping on the discharge from pumps is to be taken as the pump pressure at full rated speed against a shut valve. Where a safety valve or other protective device is fitted to restrict the pressure to a lower value than the shut valve load, the design pressure is to be the highest set pressure of the device.

1.3.4 For design pressure of steering gear components and piping, *see* Ch 19,3.1.5.

1.4 Design temperature

1.4.1 The design temperature is to be taken as the maximum temperature of the internal fluid, but in no case is it to be less than 50°C.

1.4.2 In the case of pipes for superheated steam, the temperature is to be taken as the designed operating steam temperature for the pipeline, provided that the temperature at the superheater outlet is closely controlled. Where temperature fluctuations exceeding 15°C above the designed temperature are to be expected in normal service, the steam temperature to be used for determining the allowable stress is to be increased by the amount of this excess.

1.5 Classes of pipes

1.5.1 Pressure piping systems are divided into three classes for the purpose of assigning appropriate testing requirements, types of joints to be adopted, heat treatment and weld procedure.

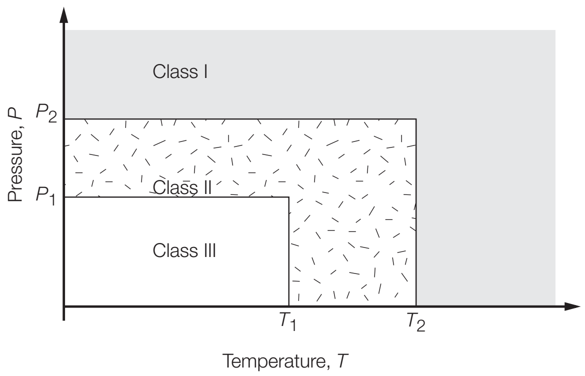
1.5.2 Dependent on the service for which they are intended, Class II and III pipes are not to be used for design pressure or temperature conditions in excess of those shown in Table 12.1.1. Where either the maximum design pressure or temperature exceeds that applicable to Class II pipes, Class I pipes are to be used. To illustrate this, *see* Fig. 12.1.1.

Table 12.1.1 Maximum pressure and temperature conditions for Class II and III piping systems

Piping system	Class II		Class III	
	p	T	p	T
	bar	°C	bar	°C
Steam	16,0	300	7,0	170
Thermal oil	16,0	300	7,0	150
Flammable Liquids, *see* Note 1	16,0	150	7,0	60
Other media	40,0	300	16,0	200
Cargo oil	40,0	300	16,0	200

NOTE
1. Flammable liquids include: oil fuel, lubricating oil and flammable hydraulic oil.
2. For grey cast iron, *see also* 4.2.2.

1.5.3 In addition to the pressure piping systems in Table 12.1.1, Class III pipes may be used for open ended piping, e.g. overflows, vents, boiler waste steam pipes, open ended drains, etc.



NOTE
T_1 and P_1 correspond to the maximum temperatures and pressures for a Class III piping system and T_2 and P_2 to those for a Class II piping system depending on the service.

Fig. 12.1.1 Classes of piping system

1.6 Materials

1.6.1 Materials for ferrous castings and forgings of Class I and Class II piping systems are to be produced at a works approved by Lloyd's Register (hereinafter referred to as 'LR') and are in general to be tested in accordance with the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

1.6.2 The manufacturer's certificate validated by LR for materials for pipes, valves and fittings of Class I and Class II piping systems will be accepted in lieu of LR's materials certificate where the maximum conditions are less than shown in Table 12.1.2. *See* Ch 1,3.1.3(b) of the Rules for Materials.

Table 12.1.2 Maximum conditions for pipes, valves and fittings for which manufacturer's materials test certificate is acceptable

Material	Working temperature °C	DN = nominal diameter, mm p_W = working pressure, bar
Carbon and low alloy steel Austenitic stainless steel Spheroidal or nodular cast iron	< 300	DN < 50 or p_W x DN < 2500
Copper alloy	< 200	DN < 50 or p_W x DN < 1500

1.6.3 The manufacturer's certificate validated by LR for materials for valves and fittings and valves on the collision bulkhead equal to or less than 500 mm nominal diameter will be accepted in lieu of LR's materials certificate where the valves and fittings are in accordance with a recognised National Standard applicable to the intended application and are manufactured and tested in accordance with the appropriate requirements of the Rules for Materials. *See* Ch 1,3.1.3(b) of the Rules for Materials.

Section 2
Carbon and low alloy steels

2.1 Carbon and low alloy steel pipes, valves and fittings

2.1.1 Materials for Class I and Class II piping systems, also for valves at the side of the unit, and fittings and valves on the collision bulkhead, are to be manufactured and tested in accordance with the appropriate requirements of the Rules for Materials, *see also* 1.6.

2.1.2 Materials for Class III piping systems are to be manufactured and tested in accordance with the requirements of acceptable national specifications. Pipes having forge butt welded longitudinal seams are not to be used for oil fuel systems, for heating coils in oil tanks, or for pressures exceeding 4,0 bar (4,1 kgf/cm^2). The manufacturer's certificate will be acceptable and is to be provided for each consignment of material. *See* Ch 1,3.1.3(c) of the Rules for Materials.

2.1.3 Steel pipes, valves and fittings may be used within the temperature limits indicated in Tables 12.2.1 and 12.2.2. Where rimming steel is used for pipes manufactured by electric resistance or induction welding processes, the design temperature is limited to 400°C, *see* Ch 6,3 of the Rules for Materials.

2.2 Wrought steel pipes and bends

2.2.1 The maximum permissible design stress, σ, is to be taken as the lowest of the following values:

$$\sigma = \frac{E_t}{1,6} \qquad \sigma = \frac{R_{20}}{2,7} \qquad \sigma = \frac{S_R}{1,6}$$

where

E_t = specified minimum lower yield or 0,2 per cent proof stress at the design temperature; in the case of stainless steel, the 1,0 per cent proof stress at design temperature is to be used

R_{20} = specified minimum tensile strength at ambient temperature

S_R = average stress to produce rupture in 100 000 hours at the design temperature

Values of the maximum permissible design stress, σ, obtained from the properties of the steels specified in Chapter 6 of the Rules for Materials are shown in Tables 12.2.1 and 12.2.2. For intermediate values of specified minimum strengths and temperatures, values of the permissible design stress may be obtained by interpolation.

2.2.2 Where it is proposed to use, for high temperature service, alloy steels other than those detailed in Table 12.2.2 particulars of the tube sizes, design conditions and appropriate national or proprietary material specifications are to be submitted for consideration.

2.2.3 The minimum thickness, t, of straight steel pipes is to be determined by the following formula:

$$t = \left(\frac{pD}{20\sigma\, e + p} + c\right)\frac{100}{100 - a} \text{ mm}$$

$$\left(t = \left(\frac{pD}{2\sigma\, e + p} + c\right)\frac{100}{100 - a} \text{ mm}\right)$$

where

p, D, e and a are as defined in 1.2.1

c is obtained from Table 12.2.3

σ is defined in 2.2.1 and obtained from Table 12.2.1 and Table 12.2.2

For pipes passing through tanks, an additional corrosion allowance is to be added to take account of external corrosion; the addition will depend on the external medium and the value is to be in accordance with Table 12.2.3. Where the pipes are efficiently protected, the corrosion allowance may be reduced by not more than 50 per cent.

2.2.4 The minimum thickness, t_b, of a straight steel pipe to be used for a pipe bend is to be determined by the following formula, except where it can be demonstrated that the use of a thickness less than t_b would not reduce the thickness below t at any point after bending:

$$t_b = \left[\left(\frac{pD}{20\sigma\, e + p}\right)\left(1 + \frac{D}{2,5R}\right) + c\right]\frac{100}{100 - a} \text{ mm}$$

$$\left(t_b = \left[\left(\frac{pD}{2\sigma\, e + p}\right)\left(1 + \frac{D}{2,5R}\right) + c\right]\frac{100}{100 - a} \text{ mm}\right)$$

where

p, D, R, e and a are as defined in 1.2.1

σ and c are as defined in 2.2.3. In general, R is to be not less than 3D.

2.2.5 Where the minimum thickness calculated by 2.2.3 or 2.2.4 is less than that shown in Table 12.2.4, the minimum nominal thickness for the appropriate standard pipe size shown in the Table is to be used. No allowance is required for negative tolerance, corrosion or reduction in thickness due to bending on this nominal thickness. For larger diameters, the minimum thickness will be considered. For threaded pipes, where permitted, the minimum thickness is to be measured at the bottom of the thread.

2.2.6 For sounding pipes, except those for cargo tanks with cargo having a flash point of less than 60°C, the minimum thickness is intended to apply to the part outside the tank.

2.2.7 For air, bilge, ballast, fuel, overflow, sounding and venting pipes as listed in Table 12.2.4, where the pipes are efficiently protected against corrosion, the thickness may be reduced by not more than 1 mm.

2.2.8 The internal diameter for bilge, venting and overflow pipes listed in Table 12.2.4 is to be not less than 50 mm. The internal diameter for sounding pipes is to be not less than 32 mm.

Table 12.2.1 Carbon and carbon-manganese steel pipes

Specified minimum tensile strength, N/mm^2 (kgf/mm^2)	Maximum permissible stress, N/mm^2 (kgf/cm^2)												
	Maximum design temperature, °C												
	50	100	150	200	250	300	350	400	410	420	430	440	450
320 (33)	107 (1091)	105 (1070)	99 (1010)	92 (938)	78 (795)	62 (632)	57 (581)	55 (561)	55 (561)	54 (551)	54 (551)	54 (551)	49 (500)
360 (37)	120 (1224)	117 (1193)	110 (1122)	103 (1050)	91 (928)	76 (775)	69 (704)	68 (693)	68 (693)	68 (693)	64 (653)	56 (571)	49 (500)
410 (42)	136 (1387)	131 (1336)	124 (1264)	117 (1193)	106 (1081)	93 (948)	86 (877)	84 (857)	79 (806)	71 (724)	64 (653)	56 (571)	49 (500)
460 (47)	151 (1540)	146 (1489)	139 (1417)	132 (1346)	122 (1244)	111 (1132)	101 (1030)	99 (1010)	98 (999)	85 (876)	73 (744)	62 (632)	53 (540)
490 (50)	160 (1632)	156 (1591)	148 (1509)	141 (1438)	131 (1336)	121 (1234)	111 (1132)	109 (1111)	98 (999)	85 (867)	73 (744)	62 (632)	53 (540)

Table 12.2.2 Alloy steel pipes

Type of steel	Specified minimum tensile strength, N/mm^2 (kgf/mm^2)	Maximum permissible stress, N/mm^2 (kgf/cm^2)									
		Maximum design temperature, °C									
		50	100	200	300	350	400	440	450	460	470
1 Cr $^1/_2$ Mo	440 (46)	159 (1621)	150 (1530)	137 (1397)	114 (1162)	106 (1081)	102 (1040)	101 (1030)	101 (1030)	100 (1020)	99 (1010)
$2^1/_4$ Cr 1 Mo annealed	410 (42)	76 (775)	67 (683)	57 (581)	50 (510)	47 (479)	45 (459)	44 (449)	43 (438)	43 (438)	42 (428)
$2^1/_4$ Cr 1 Mo normalised and tempered, *see* Note 1	490 (50)	167 (1703)	163 (1662)	153 (1550)	144 (1468)	140 (1428)	136 (1387)	130 (1326)	128 (1305)	127 (1295)	116 (1183)
$2^1/_4$ Cr 1 Mo normalised and tempered, *see* Note 2	490 (50)	167 (1703)	163 (1662)	153 (1560)	144 (1468)	140 (1428)	136 (1387)	130 (1326)	122 (1244)	114 (1162)	105 (1071)
$^1/_2$ Cr $^1/_2$ Mo $^1/_4$ V	460 (47)	166 (1693)	162 (1652)	147 (1499)	120 (1224)	115 (1173)	111 (1132)	106 (1081)	105 (1071)	103 (1050)	102 (1040)
		Maximum design temperature, °C									
		480	490	500	510	520	530	540	550	560	570
1 Cr $^1/_2$ Mo	440 (46)	98 (999)	97 (989)	91 (928)	76 (775)	62 (632)	51 (520)	42 (428)	34 (347)	27 (275)	22 (224)
$2^1/_4$ Cr 1 Mo annealed	410 (42)	42 (428)	42 (428)	41 (418)	41 (418)	41 (418)	40 (408)	40 (408)	40 (408)	37 (377)	32 (326)
$2^1/_4$ Cr 1 Mo normalised and tempered, *see* Note 1	490 (50)	106 (1081)	96 (979)	86 (877)	76 (775)	67 (683)	58 (591)	49 (500)	43 (438)	37 (377)	32 (326)
$2^1/_4$ Cr 1 Mo normalised and tempered, *see* Note 2	490 (50)	96 (979)	88 (897)	79 (806)	72 (734)	64 (653)	56 (571)	49 (500)	43 (438)	37 (377)	32 (326)
$^1/_2$ Cr $^1/_2$ Mo $^1/_4$ V	460 (47)	101 (1030)	99 (1010)	97 (989)	94 (959)	82 (836)	72 (734)	62 (632)	53 (540)	45 (459)	37 (377)

NOTES
1. Maximum permissible stress values applicable when the tempering temperature does not exceed 750°C.
2. Maximum permissible stress values applicable when the tempering temperature exceeds 750°C.

Table 12.2.3 Values of *c* for steel pipes

Piping service	*c* mm
Superheated steam systems	0,3
Saturated steam systems	0,8
Steam coil systems in cargo tanks	2,0
Feed water for boilers in open circuit systems	1,5
Feed water for boilers in closed circuit systems	0,5
Blow down (for boilers) systems	1,5
Compressed air systems	1,0
Hydraulic oil systems	0,3
Lubricating oil systems	0,3
Oil fuel systems	1,0
Cargo oil systems	2,0
Refrigerating plants	0,3
Fresh water systems	0,8
Sea-water systems in general	3,0

2.3 Pipe joints – General

2.3.1 Joints in pressure pipelines may be made by:

- Screwed-on or welded-on bolted flanges, *see* 2.5 and 2.6.
- Butt welds between pipes or between pipes and valve chests or other fittings, *see* 2.6.
- Socket weld joints, *see* 2.8.
- Welded sleeve joints, *see* 2.9.
- Threaded sleeve joints, *see* 2.10.
- Special types of approved joints that have been shown to be suitable for the design conditions. Details are to be submitted for consideration.

2.3.2 The dimensions and materials of flanges, gaskets and bolting, and the pressure – temperature rating of bolted flanges in pressure pipelines, are to be in accordance with National or other established Standards.

2.3.3 With the welded pressure piping systems referred to in 2.3.1 it is desirable that a few flanged joints be provided at suitable positions to facilitate installation, cold 'pull up' and inspection at Periodical Surveys.

2.3.4 Piping with joints is to be adequately adjusted, aligned and supported. Supports or hangers are not to be used to force alignment of piping at the point of connection.

2.3.5 Pipes passing through, or connected to, watertight decks are to be continuous or provided with an approved bolted or welded connection to the deck or bulkhead.

2.3.6 Consideration will be given to accepting joints in accordance with a recognised National Standard which is applicable to the intended service and media conveyed.

2.4 Steel pipe flanges

2.4.1 Flanges may be cut from plates or may be forged or cast. The material is to be suitable for the design temperature. Flanges may be attached to the pipes by screwing and expanding or by welding. Alternative methods of flange attachment may be accepted provided details are submitted for consideration.

2.4.2 Flange attachments to pipes and pressure – temperature ratings in accordance with National or other approved Standards will be accepted.

Table 12.2.4 Minimum thickness for steel pipes

External diameter, *D*, in mm	Pipes in general, in mm	Venting, overflow and sounding pipes for structural tanks, in mm	Bilge, ballast and general sea-water pipes, in mm	Bilge, air, overflow and sounding pipes through ballast and fuel tanks, ballast lines through fuel tanks and fuel lines through ballast tanks, in mm
10,2–12	1,6	—	—	—
13,5–19	1,8	—	—	—
20	2,0	—	—	—
21,3–25	2,0	—	3,2	—
26,9–33,7	2,0	—	3,2	—
38–44,5	2,0	4,5	3,6	6,3
48,3	2,3	4,5	3,6	6,3
51–63,5	2,3	4,5	4,0	6,3
70	2,6	4,5	4,0	6,3
76,1–82,5	2,6	4,5	4,5	6,3
88,9–108	2,9	4,5	4,5	7,1
114,3–127	3,2	4,5	4,5	8,0
133–139,7	3,6	4,5	4,5	8,0
152,4–168,3	4,0	4,5	4,5	8,8
177,8	4,5	5,0	5,0	8,8
193,7	4,5	5,4	5,4	8,8
219,1	4,5	5,9	5,9	8,8
244,5–273	5,0	6,3	6,3	8,8
298,5–368	5,6	6,3	6,3	8,8
406,4–457,2	6,3	6,3	6,3	8,8

NOTE
The pipe diameters and wall thicknesses given in the Table are based on common International Standards. Diameter and thickness according to other National or International Standards will be considered.

2.5 Screwed-on flanges

2.5.1 Where flanges are secured by screwing, as indicated in Fig. 12.2.1, the pipe and flange are to be screwed with a vanishing thread and the diameter of the screwed portion of the pipe over the thread is not to be appreciably less than the outside diameter of the unscrewed pipe. After the flange has been screwed hard home the pipe is to be expanded into the flange.

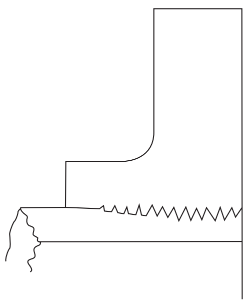


Fig. 12.2.1 Screwed-on flange

2.5.2 The vanishing thread on a pipe is to be not less than three pitches in length, and the diameter at the root of the thread is to increase uniformly from the standard root diameter to the diameter at the top of the thread. This may be produced by suitably grinding the dies, and the flange should be tapered out to the same formation.

2.5.3 Such screwed and expanded flanges may be used for steam for a maximum design pressure of 30,0 bar (30,5 kgf/cm^2) and a maximum design temperature of 370°C and for feed for a maximum design pressure of 50 bar (51 kgf/cm^2).

2.6 Welded-on flanges, butt welded joints and fabricated branch pieces

2.6.1 The types of welded-on flanges are to be suitable for the pressure, temperature and service for which the pipes are intended.

2.6.2 Typical examples of welded-on flange attachments are shown in Fig. 12.2.2, and limiting design conditions for flange types (a) to (f) are shown in Table 12.2.5.

2.6.3 Butt welded joints are generally to be of the full penetration type and are to meet the requirements of Chapter 13 of the Rules for Materials.

2.6.4 Welded-on flanges are not to be a tight fit on the pipes. The maximum clearance between the bore of the flange and the outside diameter of the pipe is to be 3 mm at any point, and the sum of the clearances diametrically opposite is not to exceed 5 mm.

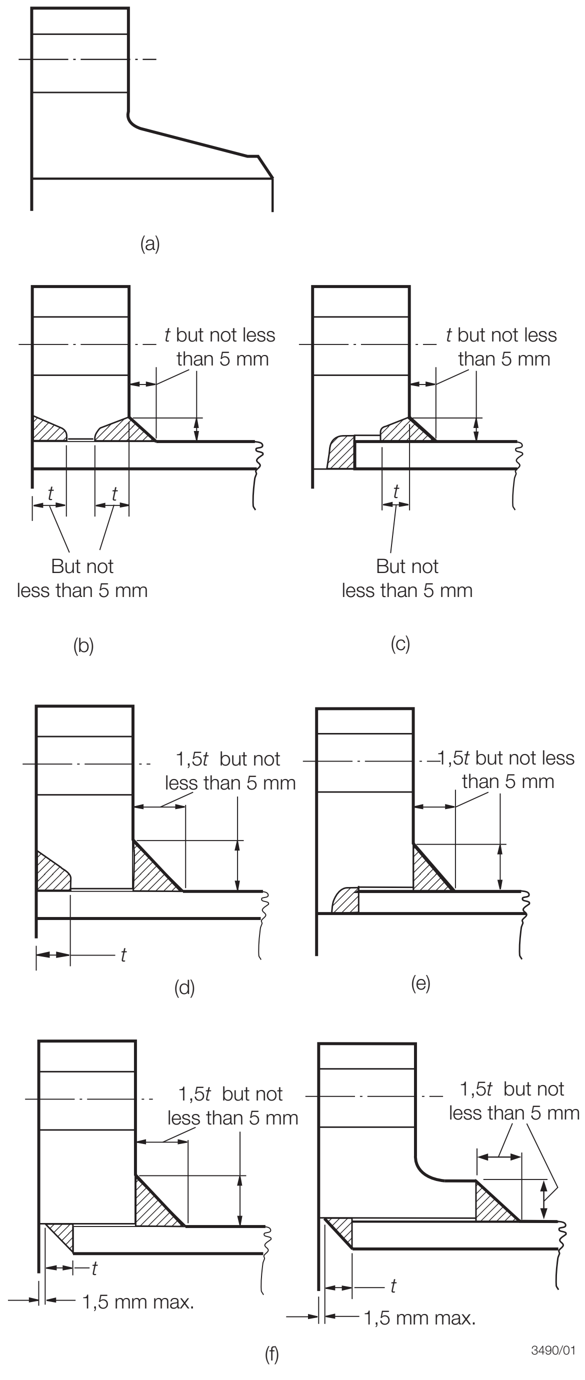


Fig. 12.2.2 Typical welded-on flanges

2.6.5 Where butt welds are employed in the attachment of flange type (a), in pipe-to-pipe joints or in the construction of branch pieces, the adjacent pieces are to be matched at the bores. This may be effected by drifting, roller expanding or machining, provided that the pipe wall is not reduced below the designed thickness. If the parts to be joined differ in wall thickness, the thicker wall is to be gradually tapered to the thickness of the thinner at the butt joint. The welding necks of valve chests are to be sufficiently long to ensure that the valves are not distorted as the result of welding and subsequent heat treatment of the joints.

Table 12.2.5 Limiting design conditions for flange types

Flange type	Maximum pressure	Maximum temperature, in °C	Maximum pipe o.d., in mm	Minimum pipe bore, in mm
(a)	Pressure-temperature ratings to be in accordance with a Recognised Standard	No restriction	No restriction	No restriction
(b)		No restriction	168,3 for alloy steels*	No restriction
(c)		No restriction	168,3 for alloy steels*	75
(d)		425	No restriction	No restriction
(e)		425	No restriction	75
(f)		425	No restriction	No restriction

* No restriction for carbon steels

2.6.6 Where backing rings are used with flange type (a) they are to fit closely to the bore of the pipe and should be removed after welding. The rings are to be made of the same material as the pipes or of mild steel having a sulphur content not greater than 0,05 per cent.

2.6.7 Branches may be attached to pressure pipes by means of welding provided that the pipe is reinforced at the branch by a compensating plate or collar or other approved means, or, alternatively, that the thickness of pipe and branch is increased to maintain the strength of the pipe. These requirements also apply to fabricated branch pieces.

2.6.8 Welding may be carried out by means of the shielded metal arc, inert gas metal arc, oxy-acetylene or other approved process, but in general oxy-acetylene welding is suitable only for flange type (a) and is not to be applied to pipes exceeding 100 mm diameter or 9,5 mm thick. The welding is to be carried out in accordance with the appropriate paragraphs of Chapter 17.

2.7 Loose flanges

2.7.1 Loose flange designs as shown in Fig. 12.2.3 may be used provided they are in accordance with a recognised National or International Standard.

2.7.2 Loose flange designs where the pipe end is flared as shown in Fig 12.2.3(b) are only to be used for water pipes and on open ended lines.

2.8 Socket weld joints

2.8.1 Socket weld joints may be used in Class III systems with carbon steel pipes of any outside diameter. Socket weld fittings are to be of forged steel and the material is to be compatible with the associated piping. In particular cases, socket welded joints may be permitted for piping systems of Class I and II having outside diameter not exceeding 88,9 mm. Such joints are not to be used where fatigue, severe erosion or crevice corrosion is expected to occur or where toxic media are conveyed. *See also* Ch 10,14.4.9.

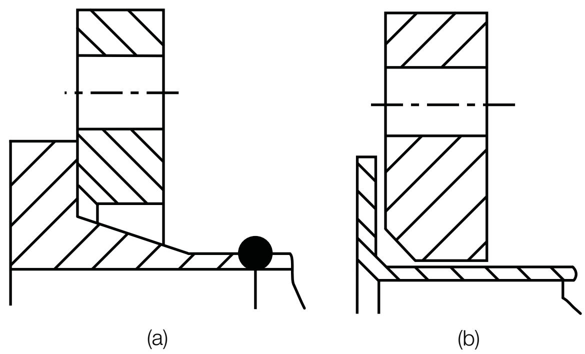


Fig. 12.2.3 Loose flange arrangements

2.8.2 The thickness of the socket weld fittings is to meet the requirements of 2.2.3 but is to be not less than 1,25 times the nominal thickness of the pipe or tube. The diametrical clearance between the outside diameter of the pipe and the bore of the fitting is not to exceed 0,8 mm, and a gap of approximately 1,5 mm is to be provided between the end of the pipe and the bottom of the socket. *See also* Ch 13,5.2.9 of the Rules for Materials.

2.8.3 The leg lengths of the fillet weld connecting the pipe to the socket weld fitting are to be such that the throat dimension of the weld is not less than the nominal thickness of the pipe or tube.

2.9 Welded sleeve joints

2.9.1 Welded sleeve joints may be used in Class III systems with carbon steel pipes of any outside diameter. In particular cases, welded sleeve joints may be permitted for piping systems of Class I and II having outside diameter not exceeding 88,9 mm. Such joints are not to be used where fatigue, severe erosion or crevice corrosion is expected to occur or where toxic media are conveyed.

2.9.2 Welded sleeve joints are not to be used in the following locations:

- Bilge pipes in way of deep tanks.
- Cargo oil piping outside of the cargo area for bow or stern loading/discharge.
- Air and sounding pipes passing through cargo tanks.

2.9.3 Welded sleeve joints may be used in piping systems for the storage, distribution and utilisation of oil fuel, lubricating or other flammable oil systems in machinery spaces provided they are located in readily visible and accessible positions. *See also* Ch 14,2.9.14.

2.9.4 Welded sleeve joints are not to be used at deck/bulkhead penetrations that require continuous pipe lengths.

2.9.5 The thickness of the sleeve is to satisfy the requirements of 2.2.3 and Table 12.2.4 but is to be not less than 1,42 times the nominal thickness of the pipe in order to satisfy the throat thickness requirement in 2.9.6. The radial clearance between the outside diameter of the pipe and the internal diameter of the sleeve is not to exceed 1 mm for pipes up to a nominal diameter of 50 mm, 2 mm on diameters up to 200 mm nominal size and 3 mm for larger size pipes. The pipe ends are to be separated by a clearance of approximately 2 mm at the centre of the sleeve.

2.9.6 The sleeve material is to be compatible with the associated piping and the leg lengths of the fillet weld connecting the pipe to the sleeve are to be such that the throat dimension of the weld is not less than the nominal thickness of the pipe or tube.

2.9.7 The minimum length of the sleeve is to conform to the following formula:

$$L_{si} = 0{,}14D + 36 \text{ mm}$$

where

L_{si} is the length of the sleeve
D is defined in 1.2.1.

2.10 Threaded sleeve joints

2.10.1 Threaded sleeve joints, in accordance with National or other established Standards, may be used with carbon steel pipes within the limits given in Table 12.2.6. Such joints are not to be used where fatigue, severe erosion or crevice corrosion is expected to occur or where flammable or toxic media is conveyed.

Table 12.2.6 Limiting design conditions for threaded sleeve joints

Thread type	Outside pipe diameter, in mm		
	Class I	Class II	Class III
Tapered thread	<33,7	<60,3	<60,3
Parallel thread	–	–	<60,3

2.11 Screwed fittings

2.11.1 Screwed fittings, including compression fittings, of an approved type may be used in piping systems for pipes not exceeding 51 mm outside diameter. Where the fittings are not in accordance with an acceptable standard then LR may require the fittings to be subjected to special tests to demonstrate their suitability for the intended service and working conditions.

2.12 Other mechanical couplings

2.12.1 Pipe unions, compression couplings, or slip-on joints, as shown in Fig. 12.2.4, may be used if Type Approved for the service conditions and the intended application. The Type Approval is to be based on the results of testing of the actual joints. The acceptable use for each service is indicated in Table12.2.7 and dependence upon the Class of piping, with limiting pipe dimensions, is indicated in Table 12.2.9.

2.12.2 Where the application of mechanical joints results in a reduction in pipe wall thickness due to the use of bite type rings or other structural elements, this is to be taken into account in determining the minimum wall thickness of the pipe to withstand the design pressure.

2.12.3 Construction of mechanical joints is to prevent the possibility of tightness failure affected by pressure pulsation, piping vibration, temperature variation and other similar adverse effects occurring during operation on board.

2.12.4 Materials of mechanical joints are to be compatible with the piping material and internal and external media.

2.12.5 Mechanical joints for pressure pipes are to be tested to a burst pressure of 4 times the design pressure. For design pressures above 200 bar the required burst pressure will be specially considered.

2.12.6 In general, mechanical joints are to be of fire resistant type where required by Table 12.2.7.

2.12.7 Mechanical joints, which in the event of damage could cause fire or flooding, are not to be used in piping sections directly connected to the sea openings or tanks containing flammable fluids.

2.12.8 The mechanical joints are to be designed to withstand internal and external pressure as applicable and where used in suction lines are to be capable of operating under vacuum.

2.12.9 Generally, slip-on joints are not to be used in pipelines in cargo holds, tanks, and other spaces which are not easily accessible. Application of these joints inside tanks may only be accepted where the medium conveyed is the same as that in the tanks.

2.12.10 Unrestrained slip-on joints are only to be used in cases where compensation of lateral pipe deformation is necessary. Usage of these joints as the main means of pipe connection is not permitted.

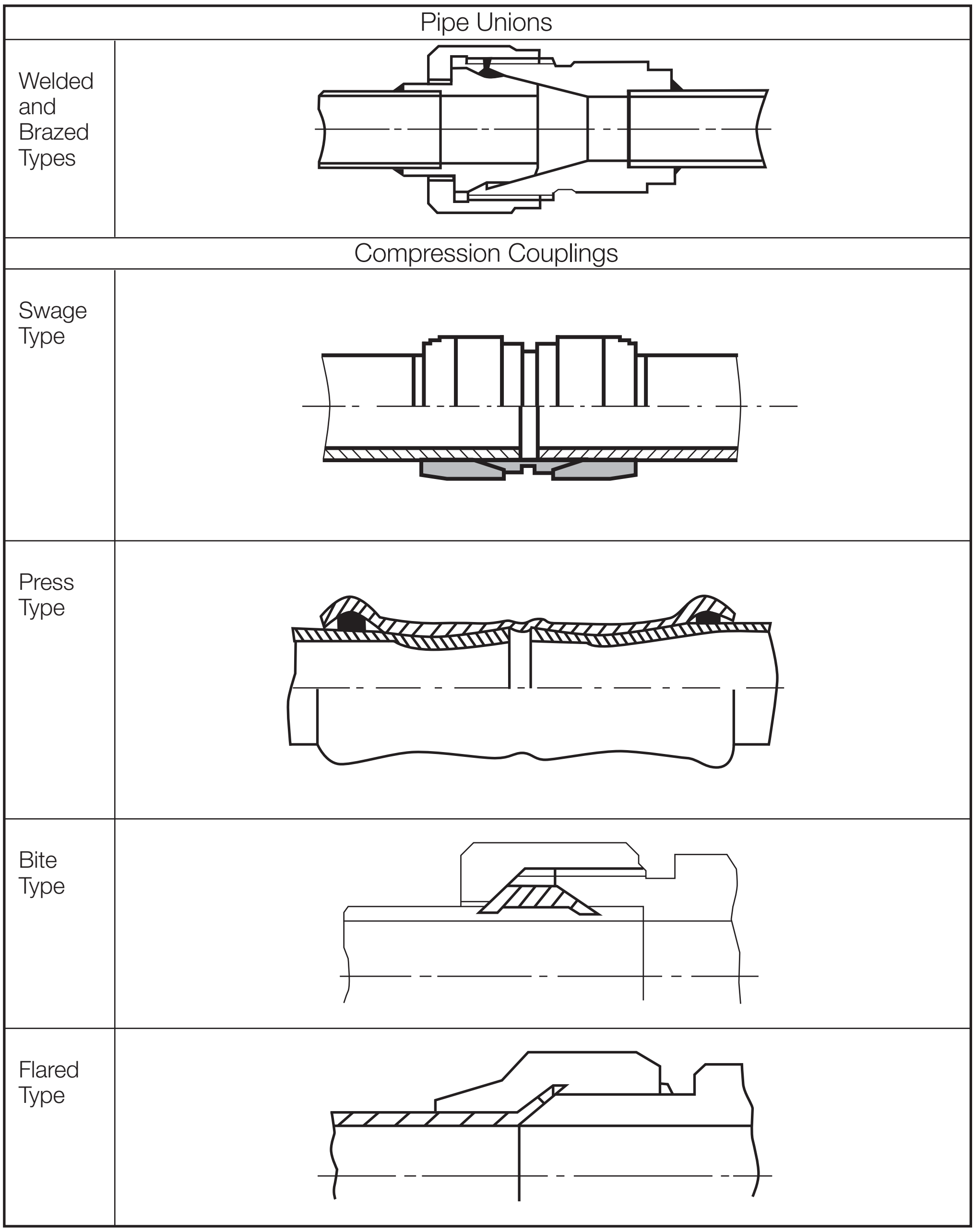


Fig. 12.2.4 Examples of mechanical joints (*see continuation*)

2.12.11 Restrained slip-on joints are permitted in steam pipes with a design pressure of 10 bar or less on the weather decks of oil and chemical tankers to accommodate axial pipe movement, *see* Ch 13,2.7.

2.13 Non-destructive testing

2.13.1 For details of non-destructive tests on piping systems, other than hydraulic tests, *see* Chapter 13 of the Rules for Materials.

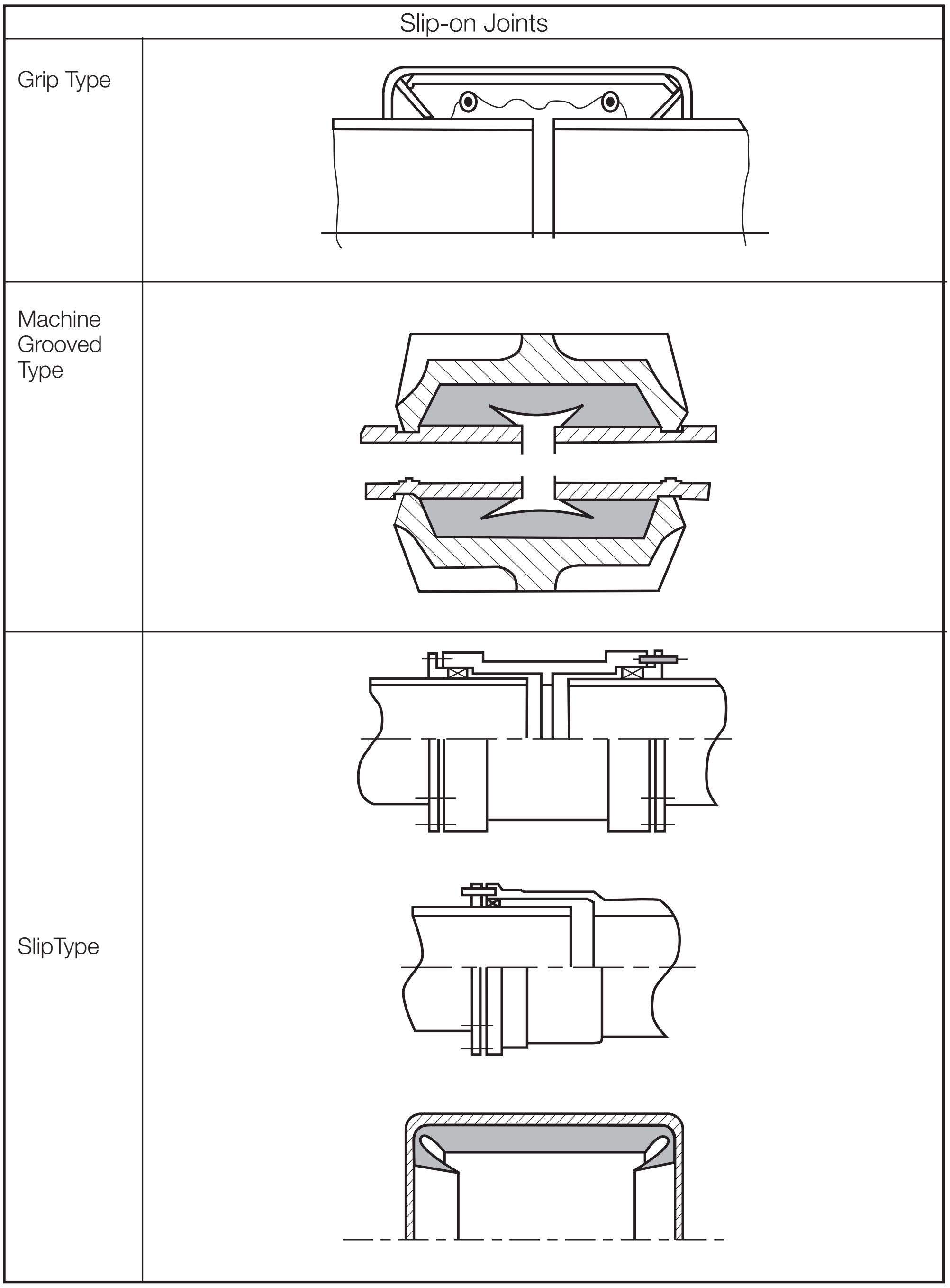


Fig. 12.2.4 Examples of mechanical joints (*conclusion*)

Table 12.2.7 Application of mechanical joints

Systems	Kind of connections		
	Pipe unions	Compression couplings (6)	Slip-on joints
Flammable fluids (Flash point <60°)			
Cargo oil lines	+	+	+5
Crude oil washing lines	+	+	+5
Vent lines	+	+	+3
Inert gas			
Water seal effluent lines	+	+	+
Scrubber effluent lines	+	+	+
Main lines	+	+	+2,5
Distribution lines	+	+	+5
Flammable fluids (Flash point > 60°)			
Cargo oil lines	+	+	+5
Fuel oil lines	+	+	+2,3
Lubricating oil lines	+	+	+2,3
Hydraulic oil	+	+	+2,3
Thermal oil	+	+	+2,3
Sea-water			
Bilge lines	+	+	+1
Fire main and water spray	+	+	+3
Foam system	+	+	+3
Sprinkler system	+	+	+3
Ballast system	+	+	+1
Cooling water system	+	+	+1
Tank cleaning services	+	+	+
Non-essential systems	+	+	+
Fresh water			
Cooling water system	+	+	+1
Condensate return	+	+	+1
Non-essential system	+	+	+
Sanitary/Drains/Scuppers			
Deck drains (internal)	+	+	+4
Sanitary drains	+	+	+
Scuppers and discharge (overboard)	+	+	—
Sounding/vent			
Water tanks/Dry spaces	+	+	+
Oil tanks (f.p.> 60°C)	+	+	+2,3
Miscellaneous			
Starting/Control air (1)	+	+	—
Service air (non-essential)	+	+	+
Brine	+	+	+
CO_2 system	+	+	—
Steam	+	+	+7

KEY
+ Application is allowed
— Application is not allowed

NOTES
1. Inside machinery spaces of Category A – only approved fire resistant types.
2. Not inside machinery spaces of Category A or accommodation spaces. May be accepted in other machinery spaces provided the joints are located in easily visible and accessible positions.
3. Approved fire resistant types. Fire resistant type is a type of connection which, when installed in the system and in the event of failure caused by fire, the failure would not result in fire spread, flooding or the loss of an essential service.
4. Above freeboard deck only.
5. In pump rooms and open decks – only approved fire resistant types.
6. If compression couplings include any components which are sensitive to heat, they are to be of approved fire resistant type as required for slip-on joints.
7. *See* 2.12.11.

Table 12.2.8 Application of mechanical joints depending on class of piping

Types of joints	Classes of piping systems		
	Class I	Class II	Class III
Pipe unions			
Welded and brazed type	+(OD ≤ 60,3 mm)	+(OD ≤ 60,3 mm)	+
Compression couplings			
Swage type	–	–	+
Bite type	+(OD ≤ 60,3 mm)	+(OD ≤ 60,3 mm)	+
Flared type	+(OD ≤ 60,3 mm)	+(OD ≤ 60,3 mm)	+
Press type	–	–	+
Slip-on joints			
Machine grooved type	+	+	+
Grip type	–	+	+
Slip type	–	+	+
KEY + Application is allowed – Application is not allowed			

■ *Section 3*
Copper and copper alloys

3.1 Copper and copper alloy pipes, valves and fittings

3.1.1 Materials for Class I and Class II piping systems, also for valves at the side of the unit and fittings and valves on the collision bulkhead, are to be manufactured and tested in accordance with the requirements of Chapter 9 of the Rules for Materials, *see also* 1.6.

3.1.2 Materials for Class III piping systems are to be manufactured and tested in accordance with the requirements of acceptable National Specifications. The manufacturer's certificate will be acceptable and is to be provided for each consignment of material. *See* Ch 1,3.1.3(c) of the Rules for Materials.

3.1.3 Pipes are to be seamless, and branches are to be provided by cast or stamped fittings, pipe pressings or other approved fabrications.

3.1.4 Brazing and welding materials are to be suitable for the operating temperature and for the medium being carried. All brazing and welding are to be carried out to the satisfaction of the Surveyors.

3.1.5 In general, the maximum permissible service temperature of copper and copper alloy pipes, valves and fittings is not to exceed 200°C for copper and aluminium brass, and 300°C for copper-nickel. Cast bronze valves and fittings complying with the requirements of Chapter 9 of the Rules for Materials may be accepted up to 260°C.

3.1.6 The minimum thickness, t, of straight copper and copper alloy pipes is to be determined by the following formula:

$$t = \left(\frac{pD}{20\sigma + p} + c\right)\frac{100}{100 - a} \text{ mm}$$

$$\left(t = \left(\frac{pD}{2\sigma + p} + c\right)\frac{100}{100 - a} \text{ mm}\right)$$

where

p, D and a are as defined in 1.2.1

c = corrosion allowance
= 0,8 mm for copper, aluminium brass, and copper-nickel alloys where the nickel content is less than 10 per cent
= 0,5 mm for copper-nickel alloys where the nickel content is 10 per cent or greater
= 0 where the media are non-corrosive relative to the pipe material

σ = maximum permissible design stress, in N/mm^2 (kgf/cm^2), from Table 12.3.1. Intermediate values of stresses may be obtained by linear interpolation.

3.1.7 The minimum thickness, t_b, of a straight seamless copper or copper alloy pipe to be used for a pipe bend is to be determined by the formula below, except where it can be demonstrated that the use of a thickness less than t_b would not reduce the thickness below t at any point after bending:

$$t_b = \left[\left(\frac{p\,D}{20\sigma + p}\right)\left(1 + \frac{D}{2{,}5R}\right) + c\right]\frac{100}{100 - a} \text{ mm}$$

$$\left(t_b = \left[\left(\frac{p\,D}{2\sigma + p}\right)\left(1 + \frac{D}{2{,}5R}\right) + c\right]\frac{100}{100 - a} \text{ mm}\right)$$

where

p, D, R and a are as defined in 1.2.1

σ and c are as defined in 3.1.6. In general, R is to be not less than $3D$.

Table 12.3.1 Copper and copper alloy pipes

Pipe material	Condition of supply	Specified minimum tensile strength, N/mm^2 (kgf/mm^2)	Permissible stress, N/mm^2 (kgf/cm^2)										
			Maximum design temperature, °C										
			50	75	100	125	150	175	200	225	250	275	300
Copper	Annealed	220 (22)	41,2 (420)	41,2 (420)	40,2 (410)	40,2 (410)	34,3 (350)	27,5 (280)	18,6 (190)	–	–	–	–
Aluminium brass	Annealed	320 (33)	78,5 (800)	78,5 (800)	78,5 (800)	78,5 (800)	78,5 (800)	51,0 (520)	24,5 (250)	–	–	–	–
90/10 Copper-nickel-iron	Annealed	270 (28)	68,6 (700)	68,6 (700)	67,7 (690)	65,7 (670)	63,7 (650)	61,8 (630)	58,8 (600)	55,9 (570)	52,0 (530)	48,1 (490)	44,1 (450)
70/30 Copper-nickel	Annealed	360 (37)	81,4 (830)	79,4 (810)	77,5 (790)	75,5 (770)	73,5 (750)	71,6 (730)	69,6 (710)	67,7 (690)	65,7 (670)	63,7 (650)	61,8 (630)

3.1.8 Where the minimum thickness calculated by 3.1.6 or 3.1.7 is less than shown in Table 12.3.2, the minimum nominal thickness for the appropriate standard pipe size shown in the Table is to be used. No allowance is required for negative tolerance or reduction in thickness due to bending on this nominal thickness. For threaded pipes, where permitted, the minimum thickness is to be measured at the bottom of the thread.

Table 12.3.2 Minimum thickness for copper and copper alloy pipes

Standard pipe sizes (outside diameter), in mm	Minimum overriding nominal thickness, in mm	
	Copper	Copper alloy
8 to 10	1,0	0,8
12 to 20	1,2	1,0
25 to 44,5	1,5	1,2
50 to 76,1	2,0	1,5
88,9 to 108	2,5	2,0
133 to 159	3,0	2,5
193,7 to 267	3,5	3,0
273 to 457,2	4,0	3,5
508	4,5	4,0

3.2 Heat treatment

3.2.1 Pipes which have been hardened by cold bending are to be suitably heat treated on completion of fabrication and prior to being tested by hydraulic pressure. Copper pipes are to be annealed and copper alloy pipes are to be either annealed or stress relief heat treated.

■ *Section 4* Cast iron

4.1 Spheroidal or nodular graphite cast iron

4.1.1 Spheroidal or nodular graphite iron may be accepted for bilge, ballast and cargo oil piping.

4.1.2 Spheroidal or nodular graphite iron castings for pipes, valves and fittings in Class II and Class III piping systems are to be made in a grade having a specified minimum elongation not less than 12 per cent on a gauge length of $5,65\sqrt{S_o}$, where S_o is the actual cross-sectional area of the test piece.

4.1.3 Castings for Class II systems, also for valves at the side of the unit, and fittings and valves on the collision bulkhead, are to be manufactured and tested in accordance with the requirements of Chapter 7 of the Rules for Materials.

4.1.4 Castings for Class III systems are to comply with the requirements of acceptable national specifications. A manufacturer's certificate will be accepted and is to be provided for each consignment of material for Class III systems, *see also* 1.6 and Ch 1,3.1.3(c) of the Rules for Materials.

4.1.5 Proposals for the use of this material in Class I piping systems will be specially considered, but in no case is the material to be used in systems where the design temperature exceeds 350°C.

4.1.6 Where the elongation is less than the minimum required by 4.1.2, the material is, in general, to be subject to the same limitations as grey cast iron.

4.2 Grey cast iron

4.2.1 Grey cast iron pipes, valves and fittings will, in general, be accepted in Class III piping systems except as stated in 4.2.3.

4.2.2 Grey cast iron is not to be used for pipes, valves and other fittings handling media having temperatures above 220°C or for piping subject to pressure shock, excessive strains or vibrations.

4.2.3 Grey cast iron is not to be used for the following:

- Pipes for steam systems and fire extinguishing systems.
- Pipes, valves and fittings for boiler blow-down systems and other piping systems subject to shock or vibration.
- Valves at the side of the unit and fittings, *see* Ch 13,2.5.
- Valves fitted on the collision bulkhead, *see* Ch 13,3.5.
- Bilge lines in tanks.
- Pipes and fittings in flammable oil systems where the design pressure exceeds 7 bar or the design operating temperature is greater than 60°C.
- Valves fitted to tanks containing flammable oil under static pressure.
- Valve chests and fittings for starting air systems, *see* Ch 2,7.4.3.

4.2.4 Castings for Class III piping systems are to comply with acceptable National Specifications.

Section 5
Plastics pipes

5.1 General

5.1.1 Proposals to use plastics pipes in onboard piping systems will be considered in relation to the properties of the materials, the operating conditions, the intended service and location. Details are to be submitted for approval. Special consideration will be given to any proposed service for plastics pipes not mentioned in these Rules.

5.1.2 Attention is also to be given to the *Guidelines for the Application of Plastic Pipes on Ships* contained in IMO Resolution A.753(18).

5.1.3 Plastics pipes and fittings will, in general, be accepted in Class III piping systems. Proposals for the use of plastics in Class I and Class II piping systems will be specially considered.

5.1.4 For Class I, Class II and any Class III piping systems for which there are Rule requirements, the pipes are to be of a type which has been approved by LR.

5.1.5 For domestic and similar services where there are no Rule requirements, the pipes need not be of a type which has been approved by LR. However, the fire safety aspects as referenced in 5.4, are to be considered.

5.1.6 The use of plastics pipes may be restricted by statutory requirements of the National Authority of the country in which the unit is to be registered.

5.2 Design and performance criteria

5.2.1 Pipes and fittings are to be of robust construction and are to comply with a National or other established Standard, consistent with the intended use. Particulars of pipes, fittings and joints are to be submitted for consideration.

5.2.2 The design and performance criteria of all piping systems, independent of service or location, are to meet the requirements of 5.3.

5.2.3 Depending on the service and location, the fire safety aspects are to meet the requirements of 5.4.

5.2.4 Plastics piping, connections and fittings are to be electrically conductive when:

(a) carrying fluids capable of generating electrostatic charges.
(b) passing through hazardous zones and spaces, regardless of the fluid being conveyed.

Suitable precautions against the build up of electrostatic charges are to be provided in accordance with the requirements of 5.5, *see also* Pt 6, Ch 2,1.13.

5.3 Design strength

5.3.1 The strength of pipes is to be determined by hydrostatic pressure tests to failure on representative sizes of pipe. The strength of fittings is to be not less than the strength of the pipes.

5.3.2 The nominal internal pressure, pN_i, of the pipe is to be determined by the lesser of the following:

$$pN_i \leq \frac{p_{st}}{4}$$

$$pN_i \leq \frac{p_{lt}}{2,5}$$

where

p_{st} = short term hydrostatic test failure pressure, in bar
p_{lt} = long term hydrostatic test failure pressure (100 000 hours), in bar

Testing may be carried out over a reduced period of time using suitable Standards, such as ASTM D2837 and D1598.

5.3.3 The nominal external pressure, pN_e, of the pipe, defined as the maximum total of internal vacuum and external static pressure head to which the pipe may be subjected, is to be determined by the following:

$$pN_e \leq \frac{p_{col}}{3}$$

where

p_{col} = pipe collapse pressure, in bar

The pipe collapse pressure is not to be less than 3 bar.

5.3.4 Piping is to meet these design requirements over the range of service temperature it will experience.

5.3.5 High temperature limits and pressure reductions relative to nominal pressures are to be according to a recognised standard, but in each case the maximum working temperature is to be at least 20°C lower than the minimum temperature of deflection under load of the resin or plastics material without reinforcement. The minimum heat distortion temperature is not to be less than 80°C, *see also* Ch 14,4 of the Rules for Materials.

Table 12.5.1 Typical temperature and pressure limits for thermoplastic pipes

Material	Nominal pressure, bar	Maximum permissible working pressure, bar						
		–20 to 0°C	30°C	40°C	50°C	60°C	70°C	80°C
PVC	10		7,5	6				
	16		12	9	6			
ABS	10	7,5	7,5	7	6			
	16	12	12	10,5	9	7,5	6	
HDPE	10	7,5	6					
	16	12	9,5	6				

Abbreviations
PVC Polyvinyl chloride
ABS Acrylonitrile – butadiene – styrene
HDPE High density polyethylene

Table 12.5.2 Typical temperature and pressure limits for glassfibre reinforced epoxy (GRE) and polyester (GRP) pipes

Minimum heat distortion temperature of resin	Nominal pressure, bar	Maximum permissible working pressure, bar							
		–50 to 30°C	40°C	50°C	60°C	70°C	80°C	90°C	95°C
80°C	10	10	9	7,5	6				
	16	16	14	12	9,5				
	25	16	16	16	15				
100°C	10	10	10	9,5	8,5	7	6		
	16	16	16	15	13,5	11	9,5		
	25	16	16	16	16	16	15		
135°C	10	10	10	10	10	9,5	8,5	7	6
	16	16	16	16	16	15	13,5	11	9,5
	25	16	16	16	16	16	16	16	15

5.3.6 Where it is proposed to use plastics piping in low temperature services, design strength testing is to be made at a temperature 10°C lower than the minimum working temperature.

5.3.7 For guidance, typical temperature and pressure limits are indicated in Tables 12.5.1 and 12.5.2. The Tables are related to water service only. Transport of chemicals or other media is to be considered on a case by case basis.

5.3.8 The selection of plastics materials for piping is to take account of other factors such as impact resistance, ageing, fatigue, erosion resistance, fluid absorption and material compatibility such that the design strength of the piping is not reduced below that required by these Rules.

5.3.9 Design strength values may be verified experimentally or by a combination of testing and calculation methods.

5.4 Fire performance criteria

5.4.1 Where plastics pipes are used in systems essential to the safe operation of the unit, or for containing combustible liquids or sea-water where leakage or failure could result in fire or in the flooding of watertight compartments, the pipes and fittings are to be of a type which have been fire endurance tested in accordance with the requirements of Table 12.5.3.

5.4.2 Where a fire protective coating of pipes and fittings is necessary for achieving the fire endurance standards required, the coating is to be resistant to products likely to come into contact with the piping and be suitable for the intended application.

5.5 Electrical conductivity

5.5.1 Where a piping system is required to be electrically conductive for the control of static electricity, the resistance per unit length of the pipe, bends, elbows, fabricated branch pieces, etc., is not to exceed 0,1 MΩ/m, *see also* 5.2.4.

5.5.2 Electrical continuity is to be maintained across the joints and fittings and the system is to be earthed, *see also* Pt 6, Ch 2,1.13. The resistance to earth from any point in the piping system is not to exceed 1 MΩ.

Table 12.5.3 Fire endurance requirements (*see continuation*)

Piping systems	Location										
	A Machinery spaces of Category A	B Other machinery spaces and pump rooms	C Cargo pump rooms	D Ro–Ro cargo holds	E Other dry cargo holds	F Cargo tanks	G Fuel oil tanks	H Ballast water tanks	I Cofferdams void spaces pipe tunnel and ducts	J Accommodation service and control spaces	K Open decks
CARGO (FLAMMABLE CARGOES f.p. ≤ 60°C)											
1 Cargo lines	N/A	N/A	L1	N/A	N/A	0	N/A	0[10]	0	N/A	L1[2]
2 Crude oil washing lines	N/A	N/A	L1	N/A	N/A	0	N/A	0[10]	0	N/A	L1[2]
3 Vent lines	N/A	N/A	N/A	N/A	N/A	0	N/A	0[10]	0	N/A	X
INERT GAS											
4 Water seal effluent line	N/A	N/A	0[1]	N/A	N/A	0[1]	0[1]	0[1]	0[1]	N/A	0
5 Scrubber effluent line	0[1]	0[1]	N/A	N/A	N/A	N/A	N/A	0[1]	0[1]	N/A	0
6 Main line	0	0	L1	N/A	N/A	N/A	N/A	N/A	0	N/A	L1[6]
7 Distribution lines	N/A	N/A	L1	N/A	N/A	0	N/A	N/A	0	N/A	L1[2]
FLAMMABLE LIQUIDS (f.p. > 60°C)											
8 Cargo lines	X	X	L1	X	X	N/A[3]	0	0[10]	0	N/A	L1
9 Fuel oil	X	X	L1	X	X	N/A[3]	0	0	0	L1	L1
10 Lubricating oil	X	X	L1	X	X	N/A	N/A	N/A	0	L1	L1
11 Hydraulic oil	X	X	L1	X	X	0	0	0	0	L1	L1
SEAWATER[1]											
12 Bilge main and branches	L1[7]	L1[7]	L1	X	X	N/A	0	0	0	N/A	L1
13 Fire main and water spray	L1	L1	L1	X	N/A	N/A	N/A	0	0	X	L1

Table 12.5.3 **Fire endurance requirements** (*continued*)

Piping systems	Location										
	A Machinery spaces of Category A	B Other machinery spaces and pump rooms	C Cargo pump rooms	D Ro–Ro cargo holds	E Other dry cargo holds	F Cargo tanks	G Fuel oil tanks	H Ballast water tanks	I Cofferdams void spaces pipe tunnel and ducts	J Accommodation service and control spaces	K Open decks
14 Foam system	L1	L1	L1	N/A	N/A	N/A	N/A	N/A	0	L1	L1
15 Sprinkler system	L1	L1	L3	X	N/A	N/A	N/A	0	0	L3	L3
16 Ballast	L3	L3	L3	L3	X	0[10]	0	0	0	L2	L2
17 Cooling water, essential services	L3	L3	N/A	N/A	N/A	N/A	N/A	0	0	N/A	L2
18 Tank cleaning services fixed machines	N/A	N/A	L3	N/A	N/A	0	N/A	0	0	N/A	L3[2]
19 Non-essential systems	0	0	0	0	0	N/A	0	0	0	0	0
FRESHWATER 20 Cooling water essential services	L3	L3	N/A	N/A	N/A	N/A	0	0	0	L3	L3
21 Condensate return	L3	L3	L3	0	0	N/A	N/A	N/A	0	0	0
22 Non-essential systems	0	0	0	0	0	N/A	0	0	0	0	0
SANITARY/DRAINS/ SCUPPERS 23 Deck drains (internal)	L1[4]	L1[4]	N/A	L1[4]	0	N/A	0	0	0	0	0
24 Sanitary drains (internal)	0	0	N/A	0	0	N/A	0	0	0	0	0
25 Scuppers and discharges (overboard)	0[1,8]	0[1,8]	0[1,8]	0[1,8]	0[1,8]	0	0	0	0	0[1,8]	0
SOUNDING/AIR 26 Water tanks/dry spaces	0	0	0	0	0	0[10]	0	0	0	0	0[11]

Table 12.5.3 Fire endurance requirements *(continued)*

Piping systems	Location A Machinery spaces of Category A	B Other machinery spaces and pump rooms	C Cargo pump rooms	D Ro–Ro cargo holds	E Other dry cargo holds	F Cargo tanks	G Fuel oil tanks	H Ballast water tanks	I Cofferdams void spaces pipe tunnel and ducts	J Accommodation service and control spaces	K Open decks
27 Oil tanks (f.p. > 60°C)	X	X	X	X	X	X[3]	0	0[10]	0	X	X
MISCELLANEOUS											
28 Control air	L1[5]	L1[5]	L1[5]	L1[5]	L1[5]	N/A	0	0	0	L1[5]	L1[5]
29 Service air (non-essential)	0	0	0	0	0	N/A	0	0	0	0	0
30 Brine	0	0	N/A	0	0	N/A	N/A	N/A	0	0	0
31 Auxiliary low pressure steam (≤ 7 bar)	L2	L2	0[9]	0[9]	0[9]	0	0	0	0	0[9]	0[9]

LOCATION DEFINITIONS

	Location	Definition
A	Machinery spaces of Category A	Machinery spaces of Category A as defined in SOLAS* regulation II–2/3.19.
B	Other machinery spaces and pump rooms	Spaces, other than Category A machinery spaces and cargo pump rooms, containing propulsion machinery, boilers, steam and internal combustion engines, generators and major electrical machinery, pumps, oil filling stations, refrigerating, stabilising, ventilation and air-conditioning machinery, and similar spaces, and trunks to such spaces.
C	Cargo pump rooms	Spaces containing cargo pumps and entrances and trunks to such spaces.
D	Ro-Ro cargo holds	Ro-Ro cargo holds are Ro-Ro cargo spaces and special category spaces as defined in SOLAS* regulation II–2/3.14 and 3.18.
E	Other dry cargo holds	All spaces other than Ro-Ro cargo holds used for non-liquid cargo and trunks to such spaces.
F	Cargo tanks	All spaces used for liquid cargo and trunks to such spaces.
G	Fuel oil tanks	All spaces used for oil fuel (excluding cargo tanks) and trunks to such spaces.
H	Ballast water tanks	All spaces used for ballast water and trunks to such spaces.
I	Cofferdams, voids, etc.	Cofferdams and voids are those empty spaces between two bulkheads separating two adjacent compartments.
J	Accommodation, service	Accommodation spaces, service spaces and control stations as defined in SOLAS* regulation II–2/3.10, 3.12, 3.22.
K	Open decks	Open deck spaces, as defined in SOLAS* regulation II–2/26.2.2(5).

* SOLAS 74 as amended by the 1978 SOLAS Protocol and the 1981 and 1983 amendments (consolidated text).

ABBREVIATIONS

- L1 Fire endurance test in dry conditions, 60 minutes, IMO Resolution A.753(18) Appendix 1.
- L2 Fire endurance test in dry conditions, 30 minutes, IMO Resolution A.753(18) Appendix 1.
- L3 Fire endurance test in wet conditions, 30 minutes, IMO Resolution A.753(18) Appendix 2.
- 0 No fire endurance test required.
- N/A Not applicable.
- X Metallic materials having a melting point greater than 925°C.

Table 12.5.3 Fire endurance requirements *(conclusion)*

NOTES

1. Where non-metallic piping is used, remotely controlled valves to be provided at ship's side (valve is to be controlled from outside space).
2. Remote closing valves to be provided at the cargo tanks.
3. When cargo tanks contain flammable liquids with f.p. > 60°C, '0' may replace 'N/A' or 'X'.
4. For drains serving only the space concerned, '0' may replace 'L1'.
5. When controlling functions are not required by the Rules or statutory requirements, '0' may replace 'L1'.
6. For pipe between machinery space and deck water seal, '0' may replace 'L1'.
7. For passenger vessels, 'X' is to replace 'L1'.
8. Scuppers serving open decks in positions 1 and 2, as defined in regulation 13 of the *International Convention on Load Lines, 1966*, should be 'X' throughout unless fitted at the upper end with the means of closing capable of being operated from a position above the freeboard deck in order to prevent downflooding.
9. For essential services, such as oil fuel tank heating and ship's whistle, 'X' is to replace '0'.
10. For tankers where compliance with MARPOL Annex I, Regulation 19.3.6 is required, 'N/A' is to replace '0'.
11. Air and sounding pipes on open deck are to be of substantial construction, see Ch 13,10.2.2.

5.6 Manufacture and quality control

5.6.1 All materials for plastics pipes and fittings are to be approved by LR, and are in general to be tested in accordance with Ch 14,4 of the Rules for Materials. For pipes and fittings not employing hand lay up techniques, the hydrostatic pressure test required by Ch 14,4.9 of the Rules for Materials may be replaced by testing carried out in accordance with the requirements stipulated in a National or International Standard, consistent with the intended use for which the pipe or fittings are manufactured, provided there is an effective quality system in place complying with the requirements of Ch 14,4.4 of the Rules for Materials and the testing is completed to the satisfaction of the LR Surveyor.

5.6.2 The material manufacturer's test certificate, based on actual tested data, is to be provided for each batch of material.

5.6.3 Plastics pipes and fittings are to be manufactured at a works approved by LR in accordance with agreed quality control procedures which shall be capable of detecting at any stage (e.g. incoming material, production, finished article, etc.) deviations in the material, product or process.

5.6.4 Plastics pipes are to be manufactured and tested in accordance with Ch 14,4 of the Rules for Materials. For Class III piping systems the pipe manufacturer's test certificate may be accepted in lieu of an LR Certificate and is to be provided for each consignment of pipe.

5.7 Installation and construction

5.7.1 All pipes are to be adequately but freely supported. Suitable provision is to be made for expansion and contraction to take place without unduly straining the pipes.

5.7.2 Pipes may be joined by mechanical couplings or by bonding methods such as welding and laminating.

5.7.3 Where bonding systems are used, the manufacturer or installer shall provide a written procedure covering all aspects of installation, including temperature and humidity conditions. The bonding procedure is to be approved by LR.

5.7.4 The person carrying out the bonding is to be qualified. Records are to be available to the Surveyor for each qualified person showing the bonding procedure and performance qualification, together with dates and results of the qualification testing.

5.7.5 In the case of pipes intended for essential services each qualified person is, at the place of construction, to make at least one test joint, representative of each type of joint to be used. The joined pipe section is to be tested to an internal hydrostatic pressure of four times the design pressure of the pipe system and the pressure held for not less than one hour, with no leakage or separation of joints. The bonding procedure test is to be witnessed by the Surveyor.

5.7.6 Conditions during installation, such as temperature and humidity, which may affect the strength of the finished joints, are to be in accordance with the agreed bonding procedure.

5.7.7 The required fire endurance level of the pipe is to be maintained in way of pipe supports, joints and fittings, including those between plastics and metallic pipes.

5.7.8 Where piping systems are arranged to pass through watertight bulkheads or decks, provision is to be made for maintaining the integrity of the bulkhead or deck by means of metallic bulkhead, or deck, pieces. The bulkhead pieces are to be protected against corrosion, and so constructed to be of a strength equivalent to the intact bulkhead; attention is drawn to 5.7.1, *see also* Ch 13,2.4.1. Details of the arrangements are to be submitted for approval.

5.7.9 Where a piping system is required to be electrically conductive, for the control of static electricity, continuity is to be maintained across the joints and fittings, and the system is to be earthed, *see also* Pt 6, Ch 2,1.13.

5.8 Testing

5.8.1 The hydraulic testing of pipes and fittings is to be in accordance with Section 8.

5.8.2 Where a piping system is required to be electrically conductive, tests are to be carried out to verify that the resistance to earth from any point in the system does not exceed 1 MΩ, *see also* Pt 6, Ch 2,21.2.3 of the Rules for Ships.

■ *Section 6* Valves

6.1 Design requirements

6.1.1 The design, construction and operational capability of valves is to be in accordance with an acceptable National or International Standard appropriate to the piping system. Where valves are not in accordance with an acceptable standard, details are to be submitted for consideration. Where valves are fitted, the requirements of 6.1.2 to 6.1.8 are to be satisfied.

6.1.2 Valves are to be made of steel, cast iron, copper alloy, or other approved material suitable for the intended purpose.

6.1.3 Valves having isolation or sealing components sensitive to heat are not to be used in spaces where leakage or failure caused by fire could result in fire spread, flooding or the loss of an essential service.

6.1.4 Where valves are required to be capable of being closed remotely in the event of fire, the valves, including their control gear, are to be of steel construction or of an acceptable fire tested design.

6.1.5 Valves are to be arranged for clockwise closing and are to be provided with indicators showing whether they are open or shut unless this is readily obvious. Legible nameplates are to be fitted.

6.1.6 Valves are to be so constructed as to prevent the possibility of valve covers or glands being slackened back or loosened when the valves are operated.

6.1.7 Valves are to be used within their specified pressure and temperature rating for all normal operating conditions, and are to be suitable for the intended purpose.

6.1.8 Valves intended for submerged installation are to be suitable for both internal and external media. Spindle sealing is to prevent ingress of external media at the maximum external pressure head expected in service.

■ *Section 7* Flexible hoses

7.1 General

7.1.1 A flexible hose assembly is a short length of metallic or non-metallic hose normally with prefabricated end fittings ready for installation.

7.1.2 For the purpose of approval for the applications in 7.2, details of the materials and construction of the hoses, and the method of attaching the end fittings together with evidence of satisfactory prototype testing, are to be submitted for consideration.

7.1.3 The use of hose clamps and similar types of end attachments are not be used for flexible hoses in piping systems for steam, flammable media, starting air systems or for sea-water systems where failure may result in flooding. In other piping systems, the use of hose clamps may be accepted where the working pressure is less than 5 bar and provided that there are two clamps at each end connection.

7.1.4 Flexible hoses are to be limited to a length necessary to provide for relative movement between fixed and flexibly mounted items of machinery/equipment or systems.

7.1.5 Flexible hoses are not to be used to compensate for misalignment between sections of piping.

7.1.6 Flexible hose assemblies are not to be installed where they may be subjected to torsional deformation (twisting) under normal operating conditions.

7.1.7 The number of flexible hoses in piping systems mentioned in this Section is to be kept to a minimum and to be limited for the purpose stated in 7.2.1.

7.1.8 Where flexible hoses are intended for conveying flammable fluids in piping systems that are in close proximity to hot surfaces, electrical installation or other sources of ignition, the risk of ignition due to failure of the hose assembly and subsequent release of fluids is to be mitigated as far as practicable by the use of screens or other suitable protection.

7.1.9 Flexible hoses are to be installed in clearly visible and readily accessible locations.

7.1.10 The installation of flexible hose assemblies is to be in accordance with the manufacturer's instructions and use limitations with particular attention to the following:
(a) Orientation.
(b) End connection support (where necessary).
(c) Avoidance of hose contact that could cause rubbing and abrasion.
(d) Minimum bend radii.

7.1.11 Flexible hoses are to be permanently marked by the manufacturer with the following details:
(a) Hose manufacturer's name or trademark.
(b) Date of manufacture (month/year).
(c) Designation type reference.
(d) Nominal diameter.
(e) Pressure rating
(f) Temperature rating.

Where a flexible hose assembly is made up of items from different manufacturers, the components are to be clearly identified and traceable to evidence of prototype testing.

7.2 Applications

7.2.1 Short joining lengths of flexible hoses complying with the requirements of this Section may be used, where necessary, to accommodate relative movement between various items of machinery connected to permanent piping systems. The requirements of this Section may also be applied to temporarily-connected flexible hoses or hoses of portable equipment.

7.2.2 Rubber or plastics hoses, with integral cotton or similar braid reinforcement, may be used in fresh and sea-water cooling systems. In the case of sea-water systems, where failure of the hoses could give rise to the danger of flooding, the hoses are to be suitably enclosed, as indicated in Ch 13,2.7.

7.2.3 Rubber hoses, with single, double or more closely woven integral wire braid or other suitable material reinforcement, or convoluted metal pipes with wire braid protection, may be used in bilge, ballast, compressed air, fresh water, sea-water, oil fuel, lubricating oil, Class III steam, hydraulic and thermal oil systems. Flexible hoses of plastics materials for the same purposes, such as Teflon or Nylon, which are unable to be reinforced by incorporating closely woven integral wire braid are to have suitable material reinforcement as far as practicable. Where rubber or plastics hoses are used for oil fuel supply to burners, the hoses are to have external wire braid protection in addition to the integral wire braid. Flexible hoses for use in steam systems are to be of metallic construction.

7.2.4 Flexible hoses are not to be used in high pressure fuel oil injection systems.

7.2.5 The requirements in this Section for flexible hose assemblies are not applicable to hoses intended to be used in fixed fire-extinguishing systems.

7.3 Design requirements

7.3.1 Flexible hose assemblies are to be designed and constructed in accordance with recognised National or International Standards acceptable to LR.

7.3.2 Flexible hoses are to be complete with approved end fittings in accordance with manufacturer's specification. End connections which do not have flanges are to comply with 2.12 as applicable and each type of hose/fitting combination is to be subject to prototype testing to the same standard as that required by the hose with particular reference to pressure and impulse tests.

7.3.3 Flexible hose assemblies intended for installation in piping systems where pressure pulses and/or high levels of vibration are expected to occur in service, are to be designed for the maximum expected impulse peak pressure and forces due to vibration. The tests required by 7.4 are to take into consideration the maximum anticipated in-service pressures, vibration frequencies and forces due to installation.

7.3.4 Flexible hose assemblies constructed of non-metallic materials intended for installation in piping systems for flammable media, and sea-water systems where failure may result in flooding, are to be of fire-resistant type. Fire resistance is to be demonstrated by testing to ISO 15540 and ISO 15541.

7.3.5 Flexible hose assemblies are to be suitable for the intended location and application, taking into consideration ambient conditions, compatibility with fluids under working pressure and temperature conditions consistent with the manufacturer's instructions and any other applicable requirements in the Rules.

7.4 Testing

7.4.1 Acceptance of flexible hose assemblies is subject to satisfactory prototype testing. Prototype test programmes for flexible hose assembles are to be submitted by the manufacturer and are to be sufficiently detailed to demonstrate performance in accordance with the specified Standards.

7.4.2 For a particular hose type complete with end fittings, the tests, as applicable, are to be carried out on different nominal diameters for pressure, burst, impulse and fire resistance in accordance with the requirements of the relevant Standard. The following Standards are to be used as applicable:

- ISO 6802 – *Rubber and plastics hoses and hose assemblies – Hydraulic pressure impulse test without flexing*.
- ISO 6803 – *Rubber and plastics hoses and hose assemblies – Hydraulic pressure impulse test with flexing*.
- ISO 15540 – *Ships and marine technology – Fire resistance of hose assemblies – Test methods*.
- ISO 15541 – *Ships and marine technology – Fire resistance of hose assemblies – Requirements for test bench*.
- ISO 10380 – *Pipework – Corrugated metal hoses and hose assemblies*.

Other Standards may be accepted where agreed by LR.

7.4.3 All flexible hose assemblies are to be satisfactorily prototype burst tested to an International Standard* to demonstrate they are able to withstand a pressure of not less than four times the design pressure without indication of failure or leakage.

NOTE

* The International Standards, e.g. EN or SAE for burst testing of non-metallic hoses, require the pressure to be increased until burst without any holding period at 4 x Maximum Working Pressure.

■ *Section 8* Hydraulic tests on pipes and fittings

8.1 Hydraulic tests before installation on board

8.1.1 All Class I and II pipes and their associated fittings are to be tested by hydraulic pressure to the Surveyor's satisfaction. Further, all steam, feed, compressed air and oil fuel pipes, together with their fittings, are to be similarly tested where the design pressure is greater than 3,5 bar (3,6 kgf/cm^2). The test is to be carried out after completion of manufacture and before installation on board and, where applicable, before insulating and coating.

8.1.2 Where the design temperature does not exceed 300°C, the test pressure is to be 1,5 times the design pressure, as defined in 1.3.

8.1.3 Where testing of systems or sub-systems following final assembly is specified, in addition to the requirements of 8.1.2 the lowest applicable pressure as defined in this sub-Section is to be used for testing.

8.1.4 For steel pipes and integral fittings for use in systems where the design temperature exceeds 300°C, the test pressure is to be as follows:

(a) For carbon and carbon-manganese steel pipes, the test pressure is to be twice the design pressure, as defined in 1.3.

(b) For alloy steel pipes, the test pressure is to be determined by the following formula, but need not exceed 2p:

$$p_t = 1{,}5 \frac{\sigma_{100}}{\sigma} p \quad \text{bar (kgf/cm}^2\text{)}$$

where

p_t and p are as defined in 1.2.1

σ = permissible stress for the design temperature, in N/mm^2 (kgf/cm^2), as stated in Table 13.2.2

σ_{100} = permissible stress for 100°C, in N/mm^2 (kgf/cm^2), as stated in Table 12.2.2.

8.1.5 Where alloy steels not included in Table 12.2.2 are used, the permissible stresses will be specially considered, as indicated in 2.2.2.

8.1.6 Consideration will be given to the reduction of the test pressure to not less than 1,5p, where it is necessary to avoid excessive stress in way of bends, branches, etc.

8.1.7 Valves and fittings non-integral with the piping system, intended for Classes I and II, are to be tested in accordance with recognised standards, but to not less than 1,5 times the design pressure. Where design features are such that modifications to the test requirements are necessary, alternative proposals for hydraulic tests are to be submitted for special consideration.

8.1.8 For requirements relating to valves and cocks intended to be fitted on the unit's side below the load water line, *see* Ch 13,2.5.10.

8.1.9 In no case is the membrane stress to exceed 90 per cent of the yield stress at the testing temperature.

8.2 Testing after assembly on board

8.2.1 Heating coils in tanks, gas fuel and oil fuel piping are to be tested by hydraulic pressure, after installation on board, to 1,5 times the design pressure but in no case to less than 4 bar (4,1 kgf/cm^2).

8.2.2 Where pipes specified in 8.1.1 are butt welded together during assembly on board, they are to be tested by hydraulic pressure in accordance with the requirements of 8.1 after welding. The pipe lengths may be insulated, except in way of the joints made during installation and before the hydraulic test is carried out.

8.2.3 The hydraulic test required by 8.2.2 may be omitted provided non-destructive tests by ultrasonic or radiographic methods are carried out on the entire circumference of all butt welds with satisfactory results. Where ultrasonic tests have been carried out, the manufacturer is to provide the Surveyor with a signed statement confirming that ultrasonic examination has been carried out by an approved operator and that there were no indications of defects which could be expected to have a prejudicial effect on the service performance of the piping.

8.2.4 Where bilge pipes are accepted in way of double bottom tanks or deep tanks, *see* Ch 13,7.9 and 7.10, the pipes after fitting are to be tested by hydraulic pressure to the same pressure as the tanks through which they pass.

■ *Cross-reference*

See also Ch 13,2.10 for testing after installation.

■ *Section 9*
Piping for LPG/LNG carriers, gas fuelled units and classed refrigeration systems

9.1 Scope

9.1.1 This Section is applicable to piping systems installed in LPG/LNG carriers, gas fuelled units and classed refrigeration systems for the following pipes and piping system components:

(a) Pipework – stainless steel, carbon steel and copper.
(b) Valves – normal and cryogenic service (below minus 55°C).
(c) Bellows – normal and cryogenic service (below minus 55°C).
(d) Pipe fittings – elbows, reducers, tee connections, etc.
(e) Ancillary fittings – weldolets, threadolets, thermo-pockets.

9.1.2 The following piping systems are covered by this Section:

(a) LPG/LNG cargo systems – normal cargo operations.
(b) LPG/LNG cargo systems – cargo gas to reliquefaction system.
(c) LNG cargo systems – gas burning and use of cargo as fuel.
(d) LNG Regasification system – high and low pressure.
(e) Cargo Reliquefaction system – nitrogen or mixed refrigerant.
(f) Refrigeration – independent plant used in cascade systems.
(g) Gas storage and supply systems for gas fuelled units.

9.2 Application

9.2.1 The requirements of this Section apply to pipes and piping system components, such as valves, elbows and bellows, which are to be used on gas carriers, gas fuelled units or classed refrigeration/reliquefaction systems. The requirements are also applicable to other gas cargo services such as regasification systems and gas combustion units, and are in addition to those contained in both the Rules for Ships for Liquefied Gases and relevant Sections of this Chapter where appropriate.

9.3 Classes of pipe

9.3.1 The material requirements for piping systems vary depending on the Class of the piping system. The Class of the piping system is dependent on the design pressure or temperature of the system and the pipe material used as shown in Table 12.1.1.

9.3.2 Table 12.1.1 piping systems containing LPG/LNG, cargo or fuel gas as the conveyed medium are to be treated as 'Flammable liquids'. These piping systems are to be categorised as Class II. Vapour lines are also to be categorised as Class II systems but the upper limit on pressure may be increased to 40 bar in accordance with the 'Other media'. Where higher design pressures are applied, such as in a regasification system, liquid lines above 16 bar and vapour lines above 40 bar are to be categorised as Class I. All open ended pipes, such as vent lines and pipes inside the cargo tanks may be categorised as Class III.

9.3.3 For reliquefaction and refrigeration systems Table 12.1.1 is to be applied. Nitrogen and non-toxic or non-flammable refrigerants are to be considered under the 'Other media' heading. Refrigeration systems containing ammonia are to be considered as Class I systems irrespective of the operational pressure.

9.4 Materials

9.4.1 Stainless steel pipes, valves and fittings for welded fabrication are to be grades 304L, 316L, 321 or 347 in accordance with Ch 6,5 of the Rules for Materials. For non-welded fabrications the grades 304 and 316 may be accepted.

9.4.2 The materials used in Class I and Class II systems are to be produced at a works approved by LR. Testing is to be in accordance with the Rules for Materials and Tables 6.1 and 6.4 in chapter 6 of the Rules for Ships for Liquefied Gases.

9.4.3 For stainless steel pipes, valve castings and forgings intended for service temperatures down to minus 55°C, a LR materials certificate is required unless the nominal diameter is less than 50 mm, or the nominal diameter is less than 150 mm and working pressure, in bar g, multiplied by nominal diameter, in mm, is less than 2500, where a manufacturer's material certificate is acceptable.

9.4.4 For pipe systems operating at cryogenic temperatures lower than minus 55°C, a LR materials certificate is required.

9.5 Valves and piping components independent of temperature

9.5.1 For valves and piping components fitted in the cargo piping system of LPG/LNG gas carriers, each type of valve and piping component is to have evidence of satisfactory type testing.

9.6 Valves for cryogenic temperature service

9.6.1 The tightness test required by 5.3.2.1 of the Rules for Ships for Liquefied Gases is to be conducted in accordance with a recognised National or International Code or Standard.

9.7 Valves for refrigeration service

9.7.1 For valves intended for installation in a refrigeration system with a nominal diameter of less than 150 mm, a manufacturer's certificate is acceptable. The certificate is to include details of the maximum working pressure and test pressure, and sufficient information for the LR Surveyor to assess the suitability of the equipment for the intended use. Each size and type of valve is to be supplied with its own certificate and is to be signed by a responsible person in the manufacturer's quality control department.

9.7.2 Valves with nominal diameters above 150 mm are to be supplied with a LR materials certificate in accordance with the Rules for Materials.

9.7.3 Where valves are fitted to pressure vessels, the requirements of Chapters 10 and 11 are applicable for the Class of pressure vessel. Mountings for liquefied gas pressure vessels are to comply with the Rules for Ships for Liquefied Gases. Any acceptance of manufacturer's certification in other Sections of this Chapter is not applicable to the valves fitted to pressure vessels in chapters 10 and 11 of the Rules for Ships for Liquefied Gases.

9.7.4 Any valve fitted directly onto a pressure vessel is to be considered a mounting and is required to be hydraulically pressure tested to twice the approved design pressure. *See* Ch 11,10.2.1.

9.8 Expansion bellows

9.8.1 The following plans and particulars are to be submitted:

(a) Dimensioned drawings of each type of bellows.
(b) Design calculations to show that the bellows are suitable for the intended design conditions, carried out to EJMA (Expansion Joint Manufacturers Association) standards (latest edition) or equivalent.
(c) A proposed prototype test program covering the tests detailed in 5.3.2.2 of the Rules for Ships for Liquefied Gases.
(d) Calculations to EJMA standards may be accepted, together with sample testing detailed above, in order to cover the entire size range for the type.

9.8.2 In accordance with 5.3 of the Rules for Ships for Liquefied Gases, the requirements for type testing in 9.8.3 to 9.8.7 are to be performed on each type of expansion bellows intended for use on LPG/LNG piping.

9.8.3 For each type of expansion bellows, an element of the bellows, not pre-compressed, is to be pressure tested at not less than five times the design pressure without bursting. This test is to be conducted at room temperature on each 'type' of element and need not be the complete bellows unit. A test on one element can cover other sized bellows with the same cross-sectional bellows form. The design pressure is to be at least 10 bar; bellows fitted to safety valves and vent lines may have a minimum design pressure of 5 bar in accordance with 5.2.3.3 of the Rules for Ships for Liquefied Gases. The required test duration is not to be less than 5 minutes.

9.8.4 A pressure test is to be performed on each type of expansion joint complete with all the accessories such as flanges, stays and articulations, at twice the design pressure at the extreme displacement conditions recommended by the manufacturer without permanent deformation. The test is to be undertaken at the minimum design temperature, unless the bellows material is stainless steel for which this test may be carried out at ambient temperature. The test duration is to be 30 minutes unless otherwise agreed with LR.

9.8.5 A cyclic thermal movement test, replicating the cooling down and warming up cycle which occurs during cargo loading and discharge, is to be performed on a complete expansion joint, by the application of representative external deflection resulting in bellow movement. This is to successfully withstand at least as many cycles, under the conditions of pressure, temperature, axial movement, rotational movement and transverse movement, as it will encounter in actual service. The number of cycles is to be estimated by the builder and depends on the unit's intended operating pattern and life expectancy. As a minimum, testing to 7000 cycles is to be carried out. The test is to be carried out at between 2-5 cycles per second. Testing at ambient temperature is permitted when this testing is at least as severe as testing at the service temperature. The maximum movements on the horizontal and vertical axis are to be provided by the builders and obtained from their stress analysis; however, the test can be extended to any value which is greater than that expected, or to the maximum deflection for which the bellows unit is suitable. Movements in the test need not be in both horizontal and vertical directions; but the horizontal-vertical box diagonal distance may be used. NDE testing is required after cyclic testing.

9.8.6 A cyclic fatigue test, representing unit deformation, is to be performed on a complete expansion joint, without internal pressure, by simulating the bellows movement corresponding to a compensated pipe length, for at least 2,000,000 cycles at a frequency not higher than 5 cycles per second. The test may be waived if the piping arrangement, experiences unit deformation loads. NDE is required after cyclic testing.

9.8.7 The cyclic thermal movement test and cyclic fatigue test may be waived by LR if satisfactory documentation is provided to establish the suitability of the expansion joints to withstand the expected working conditions. Where the maximum internal pressure exceeds 1,0 bar gauge, this documentation is to include sufficient test data to justify the design method used, with particular reference to correlation between calculation and test results.

9.9 Pressure testing of piping and other piping components

9.9.1 Pressure testing is to be undertaken in accordance with specific Rule requirements relating to the system in which the component is to be located.

9.9.2 The duration for which pressure tests are to be held is to be in conjunction with an applicable and recognised code or standard acceptable to LR.

9.10 Equipment documentation

9.10.1 A certificate is required for each piping component supplied to be fitted in a Class I or Class II system. This certification is required for each size and type of equipment delivered. A single certificate may cover a number of valves, provided that they are of the same type and size, and serial numbers have been included on the certificate. If the piping components are part of a system fitted to a skid or packaged unit, then the complete skid may be supplied with a single certificate stating that the package has been constructed using approved materials, approved and tested in accordance with LR Rule requirements.

■ *Section 10*
Austenitic stainless steels

10.1 Pipe thickness

10.1.1 The minimum thickness of austenitic stainless steel pipes is to be determined from the formula given in 2.2.1 and either 2.2.3 or 2.2.4 using a corrosion allowance of 0,8 mm. Values of 1,0 per cent proof stress and tensile strength of the material for use in the formula in 2.2.1 may be obtained from Table 6.5.2 in Chapter 6 of the Rules for Materials.

10.1.2 Where stainless steel is used in lubricating oil, hydraulic oil and refrigeration systems, the corrosion allowance may be reduced to 0 mm. For pipes passing through tanks, an additional corrosion allowance is to be added to take account of external corrosion; the addition will depend on the external medium and the value is to be in accordance with Table 12.2.3. Where he pipes are efficiently protected, the corrosion allowance may be reduced by not more than 50 per cent.

10.1.3 In no case is the thickness of austenitic stainless steel pipes to be less than that shown in Table 12.10.1.

Table 12.10.1 Minimum thickness for austenitic stainless steel pipes

Standard pipe sizes (outside diameter) in mm	Min. thickness in mm
10,2 to 17,2	1,0
21,3 to 48,3	1,6
60,3 to 88,9	2,0
114,3 to 168,3	2,3
219,1	2,6
273,0	2,9
323,9 to 406,4	3,6
over 406,4	4,0

APPENDIX

■ *Section 11*
Guidance notes on metal pipes for water services

11.1 General

11.1.1 These guidance notes, except where it is specifically stated, apply to sea-water piping systems.

11.1.2 In addition to the selection of suitable materials, careful attention should be given to the design details of the piping system and the workmanship in fabrication, construction and installation of the pipework in order to obtain maximum life in service.

11.2 Materials

11.2.1 Materials used in sea-water piping systems include:
- Galvanised steel.
- Steel pipes lined with rubber, plastics or stoved coatings.
- Copper.
- 90/10 copper-nickel-iron.
- 70/30 copper-nickel.
- Aluminium brass.

11.2.2 Selection of materials should be based on:
- the ability to resist general and localised corrosion, such as pitting, impingement attack and cavitation throughout all the flow velocities likely to be encountered;
- compatibility with the other materials in the system, such as valve bodies and casings, (e.g., in order to minimise bimetallic corrosion);
- the ability to resist selective corrosion, e.g., dezincification of brass, dealuminification of aluminium brass and graphitisation of cast iron;
- the ability to resist stress corrosion and corrosion fatigue; and
- the amenability to fabrication by normal practices.

11.3 Steel pipes

11.3.1 Steel pipes should be protected against corrosion, and protective coatings should be applied on completion of all fabrication, i.e. bending, forming and welding of the steel pipes.

11.3.2 Welds should be free from lack of fusion and crevices. The surfaces should be dressed to remove slag and spatter and this should be done before coating. The coating should be continuous around the ends of the pipes and on the faces of flanges.

11.3.3 Galvanising the bores and flanges of steel pipes as protection against corrosion is common practice, and is recommended as the minimum protection for pipes in sea-water systems, including those for bilge and ballast service.

11.3.4 Austenitic stainless steel pipes are not recommended for salt-water services as they are prone to pitting, particularly in polluted waters.

11.3.5 Rubber lined pipes are effective against corrosion and suitable for higher water velocities. The rubber lining should be free from defects, e.g., discontinuities, pinholes, etc., and it is essential that the bonding of the rubber to the bore of the pipe and flange face is sound. Rubber linings should be applied by firms specialising in this form of protection.

11.3.6 The foregoing comments on rubber lined pipes also apply to pipes lined with plastics.

11.3.7 Stove coating of pipes as protection against corrosion should only be used where the pipes will be efficiently protected against mechanical damage.

11.4 Copper and copper alloy pipes

11.4.1 Copper pipes are particularly susceptible to perforation by corrosion/erosion and should only be used for low water velocities and where there is no excessive local turbulence.

11.4.2 Aluminium brass and copper-nickel-iron alloy pipes give good service in reasonably clean sea-water. For service with polluted river or harbour waters, copper-nickel-iron alloy pipes with at least 10 per cent nickel are preferable. Alpha-brasses, i.e. those containing 70 per cent or more copper, must be inhibited effectively against dezincification by suitable additions to the composition. Alpha beta-brasses, (i.e., those containing less than 70 per cent copper), should not be used for pipes and fittings.

11.4.3 New copper alloy pipes should not be exposed initially to polluted water. Clean sea-water should be used at first to allow the metals to develop protective films. If this is not available the system should be filled with inhibited town mains water.

11.5 Flanges

11.5.1 Where pipes are exposed to sea-water on both external and internal surfaces, flanges should be made, preferably, of the same material. Where sea-water is confined to the bores of pipes, flanges may be of the same material or of less noble metal than that of the pipe, *see also* 2.3.

11.5.2 Fixed or loose type flanges may be used. The fixed flanges should be attached to the pipes by fillet welds or by capillary silver brazing. Where welding is used, the fillet weld at the back should be a strength weld and that in the face, a seal weld.

11.5.3 Inert gas shielded arc welding is the preferred process but metal arc welding may be used on copper-nickel-iron alloy pipes.

11.5.4 Mild steel flanges may be attached by argon arc welding to copper-nickel-iron pipes and give satisfactory service, provided that no part of the steel is exposed to the sea-water.

11.5.5 Where silver brazing is used, strength should be obtained by means of the bond in a capillary space over the whole area of the mating surfaces. A fillet braze at the back of the flange or at the face is undesirable. The alloy used for silver brazing should contain not less than 49 per cent silver.

11.5.6 The use of a copper-zinc brazing alloy is not permitted.

11.6 Water velocity

11.6.1 Water velocities should be carefully assessed at the design stage and the materials of pipes, valves, etc., selected to suit the conditions.

11.6.2 The water velocity in copper pipes should not exceed 1 m/s.

11.6.3 The water velocity in the pipes of the materials below should normally be not less than about 1 m/s in order to avoid fouling and subsequent pitting, but should not be greater than the following:

- Galvanised steel 3,0 m/s
- Aluminium brass 3,0 m/s
- 90/10 copper-nickel-iron 3,5 m/s
- 70/30 copper-nickel 5,0 m/s

11.7 Fabrication and installation

11.7.1 Attention should be given to ensuring streamlined flow and reducing entrained air in the system to a minimum. Abrupt changes in the direction of flow, protrusions into the bores of pipes and other restrictions of flow should be avoided. Branches in continuous flow lines should be set at a shallow angle to the main pipe, and the junction should be smooth.

11.7.2 Pipe bores should be smooth and clean.

11.7.3 Jointing should be flush with the bore surfaces of pipes and misalignment of adjacent flange faces should be reduced to a minimum.

11.7.4 Pipe bends should be of as large a radius as possible, and the bore surfaces should be smooth and free from puckering at these positions. Any carbonaceous films or deposits formed on the bore surfaces during the bending processes should be carefully removed. Organic substances are not recommended for the filling of pipes for bending purposes.

11.7.5 The position of supports should be given special consideration in order to minimise vibration and ensure that excessive bending moments are not imposed on the pipes.

11.7.6 Systems should not be left idle for long periods, especially where the water is polluted.

11.7.7 Strainers should be provided at the inlet to sea-water systems.

11.8 Metal pipes for fresh water services

11.8.1 Mild steel or copper pipes are normally satisfactory for service in fresh water applications. Hot fresh water, however, may promote corrosion in mild steel pipes unless the hardness and pH of the water are controlled.

11.8.2 Water with a slight salt content should not be left stagnant for long periods in mild steel pipes. Low salinity and the limited supply of oxygen in such conditions promote the formation of black iron oxide, and this may give rise to severe pitting. Where stagnant conditions are unavoidable, steel pipes should be galvanised, or pipes of suitable non-ferrous material used.

11.8.3 Copper alloy pipes should be treated to remove any carbonaceous films or deposits before the tubes are put into service.

11.8.4 Brass fittings and flanges in contact with water should be made of an alpha-brass effectively inhibited against dezincification by suitable additions to the composition.

11.8.5 Aluminium brass has been widely used as material for heat exchanger and condenser tubes, but its use in ‘once through’ systems is not recommended since, under certain conditions, it is prone to pitting and cracking.

Section

■ *Section 1* General requirements

1.1 Application

1.1.1 The requirements of this Chapter apply to piping systems used for the safe operation of the unit as distinct from the piping systems associated with drilling/process plant systems, *see* Pt 3, Ch 7,3 and 8,3. These systems are generally to be separate, but consideration will be given to cross-connections for drilling/process operations where this can be shown to be necessary.

1.1.2 Whilst the requirements satisfy the relevant regulations of the *International Convention for the Safety of Life at Sea, 1974*, and applicable amendments, attention should be given to any relevant regulations of the *International Convention for the Prevention of Pollution from Ships, 1973*, and applicable amendments, where these impact the design or construction of piping systems. Attention should also be given to any relevant statutory requirements of the National Authority of the country in which the unit is to be registered.

1.1.3 Consideration will be given to special cases or to arrangements which are equivalent to those required by these Rules. Consideration will also be given to the pumping arrangements of small units and units to be assigned class notations for restricted or special services.

1.2 Prevention of progressive flooding in damage condition

1.2.1 For units to which subdivision and damage stability requirements apply, precautions are to be taken to prevent progressive flooding between compartments resulting from damage to piping systems. For this purpose, piping systems are to be located inboard of the assumed extent of damage applicable to the unit type, *see* Pt 4, Ch 7,3.

1.2.2 Where it is not practicable to locate piping systems as required by 1.2.1, the following precautions are to be taken:
(a) Bilge suction pipes are to be provided with non-return valves of approved type.
(b) Other piping systems are to be provided with shut-off valves capable of being operated from positions accessible in the damage condition, or from above the bulkhead deck where required by the Rules, *see* Pt 4, Ch 7,3.

These valves are to be located in the compartment containing the open end or in a suitable position such that the compartment may be isolated in the event of damage to the piping system.

1.2.3 Where subdivision and damage stability requirements apply and where penetration of watertight divisions by pipes, ducts, trunks or other penetrations is necessary, arrangements are to be made to maintain the watertight integrity, *see* Pt 4, Ch 7,4.3.

1.3 Plans and particulars

1.3.1 The following plans (in diagrammatic form) and particulars are to be submitted for approval. Additional plans should not be submitted unless the arrangements are of a novel or special character affecting classification:
(a) Arrangements of air pipes and closing devices for all tanks and enclosed spaces.
(b) Sounding arrangements for all tanks, enclosed spaces and cargo holds.
(c) Arrangements of level alarms fitted in tanks, cargo holds, machinery spaces, pump-rooms and any other spaces.
(d) Arrangements of any cross-flooding or heeling tank systems.
(e) Bilge drainage arrangements for all compartments, which are to include details of location, number and capacity of pumping units on bilge service.
(f) Sea-water pumping and ballast systems.
(g) Oil fuel filling, transfer, relief and spill/drainage arrangements.
(h) Tank overflow arrangements.
(j) Arrangement of hazardous and non-hazardous drains.
(k) Sanitary water and sewage systems.
(l) Details verifying compliance with the sizing of air pipes required by 12.8.
(m) Arrangements of oil fuel piping in connection with oil burning installations and oil fired galleys.
(n) Arrangements of oil fuel burning units for boilers and thermal fluid heaters.
(o) Arrangement of boiler feed system.
(p) Arrangements of thermal fluid circulation systems.

(q) Arrangement of compressed air systems for main and auxiliary services.
(r) Arrangements of lubricating oil systems.
(s) Arrangements of flammable liquids used for control and heating systems.
(t) Arrangements of power transmission systems for services essential for safety or for the operation of the unit at sea.
(u) Arrangements of cooling water systems for main and auxiliary services.
(v) Oil fuel settling service and other oil fuel tanks not forming part of the unit's structure.
(w) Arrangements and dimensions of all steam pipes where the design pressure or temperature exceeds 16,0 bar (16,3 kgf/cm^2) or 300°C, respectively, and the outside diameter exceeds 76,1 mm, with details of flanges, bolts and weld attachments, and particulars of the material of pipes, flanges, bolts and electrodes.
(x) Details verifying compliance with the capacity of the oil fuel treatment plant required by Ch 14,3.9.1.
(y) Details verifying compliance of demands on low pressure air systems by supplying essential services as required by Ch 14,10.1.3.
(z) For water ingress detection arrangements, *see* Section 14, plans and information in accordance with Pt 6, Ch 1,1.2 and, additionally, general arrangement plans showing the spaces provided with water ingress detectors, installed equipment locations and cable routes. Details of National Administration approvals are to be included.

■ *Section 2* Construction and installation

2.1 Materials

2.1.1 Except where otherwise stated in this Chapter, pipes, valves and fittings are to be made of steel, cast iron, copper, copper alloy, or other approved material suitable for the intended service.

2.1.2 Where applicable, the materials are to comply with the relevant requirements of Chapter 12.

2.1.3 Materials sensitive to heat, such as aluminium, lead or plastics, are not to be used in systems essential to the safe operation of the unit, or for containing combustible liquids or sea-water where leakage or failure could result in fire or in the flooding of watertight compartments, *see* Chapter 12 for plastics pipes.

2.1.4 Aluminium alloy pipes are not acceptable for fire extinguishing pipes unless they are suitably protected against the effect of heat. The proposed use of aluminium alloy with appropriate insulation will be considered when it has been demonstrated that the arrangements provide equivalent structural and integrity properties compared to steel. In open and exposed locations where the insulation material is likely to suffer from mechanical damage, suitable protection is to be provided.

2.2 Pipe wall thickness

2.2.1 The minimum nominal wall thickness of steel, copper and copper alloy pipes is to be in accordance with Chapter 12.

2.2.2 Special consideration will be given to the wall thickness of pipes made of materials other than steel, copper and copper alloy.

2.3 Valves – Installation and control

2.3.1 Valves and cocks are to be fitted in places where they are at all times readily accessible, unless otherwise specifically mentioned in the Rules. Valves in cargo oil and ballast systems may be fitted inside tanks, subject to 2.3.2.

2.3.2 All valves which are provided with remote control are to be arranged for local manual operation, independent of the remote operating mechanism. For valves on the side of the unit and valves on the collision bulkhead, the means for local manual operation are to be permanently attached. For submerged valves in cargo oil and ballast systems, as permitted by 2.3.1, local manual operation may be by extended spindle or a portable hand pump. Where manual operation is by hand pump, the control lines to each submerged valve are to incorporate quick coupling connections, as close to the valve actuator as practicable, to allow easy connection of the hand pump. No fewer than two hand pumps are to be provided.

2.3.3 In the case of valves which are required by the Rules to be provided with remote control, opening and/or closing of the valves by local manual means is not to render the remote control system inoperable.

2.4 Attachment of valves to watertight plating

2.4.1 Valve chests, cocks, pipes or other fittings attached directly to the plating of tanks, and to bulkheads, flats or tunnels which are required to be of watertight construction, are to be secured by means of studs screwed through the plating or by tap bolts, and not by bolts passing through clearance holes. Alternatively, the studs or the bulkhead piece may be welded to the plating.

2.4.2 For requirements relating to valves on the collision bulkhead, *see* 3.5.4.

2.5 Valves and fittings on the side of the unit (other than those on scuppers and sanitary discharges)

2.5.1 All sea inlet and overboard discharge pipes are to be fitted with valves or cocks secured directly to the shell plating, or to the plating of fabricated steel water boxes attached to the shell plating. These fittings are to be secured by bolts tapped into the plating and fitted with countersunk heads, or by studs screwed into heavy steel pads fitted to the plating. The stud holes are not to penetrate the plating.

2.5.2 Valves on the side of the unit are to be installed, such that the section of piping immediately inboard of the valve can be removed without affecting the watertight integrity of the hull.

2.5.3 Distance pieces of short, rigid construction, and made of approved material, may be fitted between the valves and the boundary bulkheads. Distance pieces of steel may be welded to the boundary bulkhead. Details of the welded connections and of fabricated steel water boxes are to be submitted.

2.5.4 Gratings are to be fitted at all openings in the side of the unit for sea inlet valves and inlet water boxes. The net area through the gratings is to be not less than twice that of the valves connected to the sea inlets, and provision is to be made for clearing the gratings by use of low pressure steam or compressed air, *see* 2.5.9.

2.5.5 All suction and discharge valves and cocks secured directly to the shell plating of the unit are to be fitted with spigots passing through the plating, but the spigots on the valves or cocks may be omitted if these fittings are attached to pads or distance pieces which themselves form spigots in way of the shell plating. Blow-down valves or cocks are also to be fitted with a protection ring through which the spigot is to pass, the ring being on the outside of the shell plating. Where alternative forms of attachment are proposed, details are to be submitted for consideration.

2.5.6 Blow-down valves or cocks which penetrate the boundary bulkhead are to be fitted in accessible positions above the level of the working platform, and are to be provided with indicators showing whether they are open or shut. Cock handles are not to be capable of being removed unless the cocks are shut, and, if valves are fitted, the hand wheels are to be suitably retained on the spindle.

2.5.7 Sea inlet and overboard discharge valves and cocks are in all cases to be fitted in easily accessible positions and, so far as practicable, are to be readily visible. Indicators are to be provided local to the valves and cocks, showing whether they are open or shut. Provision is to be made for preventing any discharge of water into lifeboats. Inlet and discharge valves in compartments situated below the assigned loadline and located in normally unattended spaces are to be provided with remote control which is capable of operating when submerged. For column-stabilised units all sea inlet and overboard discharge valves are to be provided with remote control. Where remote operation is provided by power-activated valves for sea inlets and discharges for cooling of essential machinery or supply to fire pumps, power supply failure of the control system is not to result in the closing of open valves or the opening of closed valves. Consideration will be given to accepting bilge alarms in lieu of remote operation for surface type and self-elevating units. *See also* Section 10 and Pt 6, Ch 1. The valve spindles are to extend above the lower platform, and the hand wheels of the main cooling water sea inlet and emergency bilge suction valves are to be situated not less than 460 mm above this platform.

2.5.8 Valves on the side of the unit and fittings, if made of steel or other approved material with low corrosion resistance, are to be suitably protected against wastage.

2.5.9 The scantlings of valves and valve stools fitted with steam or compressed air clearing connections are to be suitable for the maximum pressure to which the valves and stools may be subjected.

2.5.10 Valves, cocks and distance pieces, intended for installation on the unit's side below the load waterline, are to be tested by hydraulic pressure to not less than 5 bar.

2.5.11 Where valves are provided at watertight boundaries to maintain watertight integrity, these valves should be capable of being operated from a pump-room or other normally manned space, a weather deck, or a deck which is above the final waterline after flooding. Valve position indication is to be provided at the remote control station.

2.5.12 For the drainage of weather decks, scuppers and sanitary discharges, *see* Pt 4, Ch 7.

2.6 Piping systems – Installation

2.6.1 Bilge, ballast and cooling water suction and discharge pipes are to be permanent pipes made in readily removable lengths with flanged joints, except as mentioned in 7.10, and are to be efficiently secured in position to prevent chafing or lateral movement. For joints in oil fuel piping systems, *see* Ch 14,4.5 and 4.6.

2.6.2 Where lack of space prevents the use of normal circular flanges, details of the alternative methods of joining the pipes are to be submitted.

2.6.3 Long or heavy lengths of pipes are to be supported by bearers so that no undue load is carried by the flanged connections of the pumps or fittings to which they are attached.

2.7 Provision for expansion

2.7.1 Suitable provision for expansion is to be made, where necessary, in each range of pipes.

2.7.2 Where expansion pieces are fitted, they are to be of an approved type and are to be protected against over-extension and compression. The adjoining pipes are to be suitably aligned, supported, guided and anchored. Where necessary, expansion pieces of the bellows type are to be protected against mechanical damage.

2.7.3 Expansion pieces of an approved type incorporating special quality oil resistant rubber or other suitable synthetic material may be used in cooling water lines in machinery spaces. Where fitted in sea-water lines, they are to be provided with guards which will effectively enclose, but not interfere with, the action of the expansion pieces and will reduce to the minimum practicable any flow of water into the machinery spaces in the event of failure of the flexible elements. Proposals to use such fittings in water lines for other services, including:

- ballast lines in machinery spaces, in duct keels and inside double bottom water ballast tanks, and
- bilge lines inside duct keels only, will be specially considered when plans of the pumping systems are submitted for approval.

2.7.4 For requirements relating to flexible hoses, *see* Chapter 12.

2.8 Piping in way of refrigerated chambers

2.8.1 All pipes, including scupper pipes, air pipes and sounding pipes which pass through chambers intended for the carriage or storage of refrigerated produce are to be well insulated.

2.8.2 Where the pipes referred to in 2.8.1 pass through chambers intended for temperatures of 0°C or below, they are also to be insulated from the steel structure, except in positions where the temperature of the structure is mainly controlled by the external temperature and will normally be above freezing point. Pipes passing through a deckplate within the unit side insulation, where the deck is fully insulated below and has an insulation riband on top, are to be attached to the deck plating. In the case of pipes adjacent to the shell plating, metallic contact between the pipes and the shell plating or frames is to be arranged so far as practicable.

2.8.3 The air refreshing pipes to and from refrigerated compartments need not, however, be insulated from the steel work.

2.9 Miscellaneous requirements

2.9.1 All pipes situated in chain lockers or other positions where they are liable to mechanical damage are to be efficiently protected.

2.9.2 So far as practicable, pipelines, including exhaust pipes from oil engines, are not to be led in the vicinity of switchboards or other electrical appliances in positions where the drip or escape of liquid, gas or steam from joints or fittings could cause damage to the electrical installation. Where it is not practicable to comply with these requirements, drip trays or shields are to be provided as found necessary. Short sounding pipes to tanks are not to terminate near electrical appliances, *see* 12.13.2.

2.10 Testing after installation

2.10.1 After installation on board, all steam, hydraulic, compressed air and other piping systems covered by 1.3.1, together with associated fittings which are under internal pressure, are to be subjected to a running test at the intended maximum working pressure.

■ *Cross-reference*

For guidance on metal pipes for water services, *see* Ch 12,11.

■ *Section 3*
Drainage of compartments, other than machinery spaces

3.1 General

3.1.1 All units are to be provided with efficient pumping plant having the suctions and means for drainage so arranged that any water within any compartment of the unit, or any watertight section of any compartment, can be pumped out through at least one suction when the unit is on an even keel and is either upright or has a list of not more than 5°. For this purpose, wing suctions will generally be necessary, except in short, narrow compartments where one suction can provide effective drainage under the above conditions. For column-stabilised units, bilge systems are to be capable of operating satisfactorily under the conditions as shown in Table 1.3.2 in Chapter 1. Drainage of small void spaces will be specially considered.

3.1.2 Hazardous and non-hazardous areas are to be provided with separate drainage and pumping systems.

3.1.3 In the case of dry compartments, the suctions required by 3.1.1 are, except where otherwise stated, to be branch bilge suctions, i.e. suctions connected to a main bilge line.

3.1.4 For drainage arrangements of non-self-propelled units, *see* Section 10.

3.1.5 An emergency or direct bilge suction is to be provided for emergency drainage of below deck machinery spaces and pump-rooms.

3.1.6 Suitable drainage arrangements are to be provided for cofferdams.

3.1.7 Certain compartments not provided with a bilge suction may be drained to other spaces with bilge pumping capability. Means are to be provided to detect the presence of water in such compartments which are adjacent to the sea, or to tanks containing liquids, or through which pipes conveying liquids pass. *See also* 8.1.2 and 4.5.

3.1.8 For a normally inaccessible small void compartment such as an echo sounding compartment, which is accessed from within a normally inaccessible space such as a fore peak tank, alternative drainage arrangements to those required by 3.1.1 may be considered. For such arrangements, a warning notice is to be located in a prominent position specifying the precautions to be taken prior to opening the manhole of the small void compartment. Means are to be provided to indicate flooding of the compartment without opening, such as fitting indicator plugs to the manhole. Drainage arrangements are to be submitted to LR for approval.

3.1.9 Means are to be provided for the removal of mud and debris from the chain locker drainage systems.

3.2 Tanks and cofferdams

3.2.1 All tanks (including double bottom tanks), whether used for water ballast, oil fuel or liquid cargoes, are to be provided with suction pipes, led to suitable power pumps, from the after end of each tank.

3.2.2 In general, the drainage arrangements are to be in accordance with 3.1. However, where the tanks are divided by longitudinal watertight bulkheads or girders into two or more tanks, a single suction pipe, led to the after end of each tank, will normally be acceptable.

3.2.3 Similar drainage arrangements are to be provided for cofferdams, except that the suctions may be led to the main bilge line.

3.2.4 The pumping arrangements for tanks that are intended to carry cargo oil having a flash point of 60°C or above, are also to comply with the requirements of Chapter 14, Sections 2, 3 and 4, as far as they are applicable.

3.3 Fore and after peaks

3.3.1 Fuel oil, lubrication oil and other flammable liquids are not to be carried in fore peak tanks.

3.3.2 Where the peaks are used as tanks, a power pump suction is to be led to each tank, except in the case of small tanks used for the carriage of domestic fresh water, where hand pumps may be used.

3.3.3 Where the peaks are not used as tanks, and main bilge line suctions are not fitted, drainage of both peaks may be effected by hand pump suctions, provided that the suction lift is well within the capacity of the pumps and in no case exceeds 7,3 m.

3.3.4 Except as permitted by 3.3.5, the collision bulkhead is not to be pierced below the bulkhead deck by more than one pipe for dealing with the contents of the fore peak. The pipe is to be provided with a screw-down valve capable of being operated from an accessible position above the bulkhead deck, the chest being secured to the bulkhead inside the fore peak. An indicator is to be provided to show whether the valve is open or closed. The valves may be fitted on the after side of the collision bulkhead, provided that the valve is readily accessible under all service conditions.

3.3.5 Where the fore peak is divided into two compartments, the collision bulkhead may be pierced below the bulkhead deck by two pipes (i.e., one for each compartment) provided there is no practical alternative to the fitting of a second pipe. Each pipe is to be provided with a screw-down valve, fitted and controlled as in 3.3.4.

3.4 Spaces above fore peaks, after peaks and machinery spaces on ship and barge type units

3.4.1 Provision is to be made for the drainage of the chain locker and watertight compartments above the fore peak tank by hand or power pump suctions.

3.4.2 Steering gear compartments or other small enclosed spaces situated above the after peak tank are to be provided with suitable means of drainage, either by hand or power pump bilge suctions.

3.4.3 Subject to special approval of any applicable subdivision requirements, compartments referred to in 3.6.2 that are adequately isolated from the adjacent 'tween decks, may be drained by scuppers of not less than 38 mm bore, discharging to the tunnel (or machinery space in the case of units with machinery aft) and fitted with self-closing cocks situated in well lighted and visible positions.

3.4.4 For drainage of the fore and after peaks, *see* 3.3.

3.5 Maintenance of integrity of bulkheads

3.5.1 The intactness of the machinery space bulkheads, and of tunnel plating required to be of watertight construction, is not to be impaired by the fitting of scuppers discharging to machinery space or tunnels from adjacent compartments which are situated below the bulkhead deck. These scuppers may, however, be led into a strongly constructed scupper drain tank situated in the machinery space or tunnel, but closed to these spaces and drained by means of a suction of appropriate size led from the main bilge line through a screw-down non-return valve.

3.5.2 The scupper tank air pipe is to be led to above the bulkhead deck, and provision is to be made for ascertaining the level of water in the tank.

3.5.3 Where one tank is used for the drainage of several watertight compartments, the scupper pipes are to be provided with screw-down non-return valves.

3.5.4 No drain valve or cock is to be fitted to the collision bulkhead. Drain valves or cocks are not to be fitted to other watertight bulkheads if alternative means of drainage are practicable.

3.5.5 Where drain valves or cocks are fitted to bulkheads other than the collision bulkhead, as permitted by 3.5.4, the drain valves or cocks are to be at all times readily accessible and are to be capable of being shut off from positions above the bulkhead deck. Indicators are to be provided to show whether the drains are open or shut. These arrangements are not permissible on accommodation units.

3.5.6 Bilge drain valves or cocks may be used for draining accommodation spaces.

3.5.7 For drainage of stern compartment, *see* 3.4.

3.6 Sealed void spaces including main bracings

3.6.1 Provision is to be made for detection and drainage of leakage within main bracings that are sealed against the ingress of sea water when submerged in operating conditions.

3.6.2 For the members mentioned in 3.6.1 and other regions of the unit, where numerous small compartments are provided, arrangements are to be made for venting, draining and sounding, except where flooding of one or more compartments will not materially affect the stability criteria. Nevertheless, provision is to be made for the detection of leakage in each compartment. In all cases, fault condition alarms are to be provided at the central control station.

3.6.3 Special consideration is to be given to the design and workmanship of fittings and penetrations in the bracings. *See* Pt 4, Ch 8,5.

■ *Section 4* Bilge drainage of machinery spaces

4.1 General

4.1.1 Hazardous and non-hazardous areas are to be provided with separate drainage and pumping systems.

4.1.2 The bilge drainage arrangements in the machinery space are to comply with 3.1, except that the arrangements are to be such that any water which may enter this compartment can be pumped out through at least two bilge suctions when the unit is on an even keel, and is either upright or has a list of not more than 5°. One of these suctions is to be a branch bilge suction, i.e., a suction connected to the main bilge line, and the other is to be a direct bilge suction, i.e., a suction led direct to an independent power pump. Examples of the necessary arrangements are detailed in 4.2 and 4.3.

4.1.3 In accommodation units, the drainage arrangements are to be such that machinery spaces can be pumped out under all practical conditions after a casualty, whether the unit is upright or listed.

4.1.4 High bilge water level detection systems in unattended machinery spaces are to comply with Pt 6, Ch 1,4.6.

4.2 Machinery space with double bottom

4.2.1 Where the double bottom extends the full length of the machinery space and forms bilges at the wings, it will be necessary to provide one branch and one direct bilge suction at each side.

4.2.2 Where the double bottom plating extends the full length and breadth of the compartment, one branch bilge suction and one direct bilge suction are to be led to each of two bilge wells, situated one at each side.

4.2.3 For capacity and construction of bilge wells, *see* 7.6.

4.3 Machinery space without double bottom

4.3.1 Where there is no double bottom and the rise of floor is not less than 5°, one branch and one direct bilge suction are to be led to accessible positions as near the centreline as practicable.

4.3.2 In units where the rise of floor is less than 5°, and in all accommodation units, additional bilge suctions are to be provided at the wings.

4.4 Additional bilge suctions

4.4.1 Additional bilge suctions may be required for the drainage of depressions in the tank top formed by crankpits, or other recesses, by tank tops having inverse camber or by discontinuity of the double bottom.

4.4.2 In units in which the propelling machinery is situated at the after end of the unit, it will generally be necessary for bilge suctions to be fitted in the forward wings as well as in the after end of the machinery space, but each case will be dealt with according to the size and structural arrangements of the compartment.

4.4.3 In units propelled by electrical machinery, special means are to be provided to prevent the accumulation of bilge water under the main propulsion generators and motors.

4.5 Separate machinery spaces

4.5.1 Where the machinery space is divided by watertight bulkheads to separate the boiler room(s) or auxiliary engine room(s) from the main engine room, the number and position of the branch bilge suctions in the boiler room(s) or auxiliary engine room(s) are to be the same as for holds.

4.5.2 In addition to the branch bilge suctions required by 4.5.1, at least one independent power pump direct bilge suction is to be fitted in each compartment. Similar provision is to be made in separate motor rooms of electrically propelled units.

4.5.3 In accommodation units, each independent bilge pump is to have a direct bilge suction from the space in which it is situated, but not more than two such suctions are required in any one space. Where two or more such suctions are provided, there is to be at least one suction on each side of the space.

4.5.4 Spaces housing ancillary machinery for drilling or production purposes and other compartments where fluid could accumulate are to be provided with drainage facilities. Where these compartments are below the waterline, power pump bilge suctions are to be provided. The drains and suction and discharge piping from all such compartments are not to enter the machinery spaces.

4.6 Machinery space – Emergency bilge drainage

4.6.1 In addition to the bilge suctions detailed in 4.1 to 4.5, an emergency bilge suction is to be provided in each main machinery space. This suction is to be led to the main cooling water pump from a suitable low level in the machinery space and is to be fitted with a screw-down non-return valve having the spindle so extended that the hand wheel is not less than 460 mm above the bottom platform.

4.6.2 Where two or more cooling water pumps are provided, each capable of supplying cooling water for normal power, only one pump need be fitted with an emergency bilge suction.

4.6.3 In units with steam propelling machinery, the suction is to have a diameter of at least two thirds that of the pump suction. In other units, the suction is to be the same size as the suction branch of the pump.

4.6.4 Where main cooling water pumps are not suitable for bilge pumping duties, the emergency bilge suction is to be led to the largest available power pump, which is not a bilge pump detailed in 6.1 and 6.2. This pump is to have a capacity not less than that required for a bilge pump and the bilge suction is to be the same size as that of the pump suction branch.

4.6.5 Where the pump to which the emergency bilge suction is connected is of the self-priming type, the direct bilge suction on the same side of the unit as the emergency suction may be omitted.

4.6.6 Emergency bilge suction valve nameplates are to be marked 'For emergency use only'.

4.6.7 Strum boxes are not to be fitted to the lower ends of emergency bilge suctions.

4.7 Tunnel drainage

4.7.1 The tunnel well is to be drained by a suction from the main bilge line. This well may extend to the outer bottom.

4.7.2 Where the tank top in the tunnel slopes down from aft to forward, a bilge suction is to be provided at the forward end of the tunnel, in addition to the tunnel well suction required by 4.7.1.

■ *Section 5*
Sizes of bilge suction pipes

5.1 Main bilge line

5.1.1 The diameter, d_m, of the main bilge line is to be not less than required by the following formula, to the nearest 5 mm, but in no case is the diameter to be less than that required for any branch bilge suction:

$$d_m = 1{,}68 \sqrt{L\,(B + D)} + 25 \text{ mm}$$

where

d_m = internal diameter of main bilge line, in mm
B = greatest moulded breadth of unit, in metres
D = moulded depth to bulkhead deck, in metres
L = Rule length of unit as defined in Pt 4, Ch 1,5.1, in metres, for units other than accommodation units
= length between perpendiculars at the extremities of the deepest subdivision load line, in metres, for accommodation units.

5.2 Branch bilge suctions

5.2.1 The internal diameter, d_m, of branch bilge suction pipes to compartments is to be not less than required by the following formula, to the nearest 5 mm, but in no case is the diameter of any suction to be less than 50 mm:

$$d_b = 2{,}15 \sqrt{C\,(B + D)} + 25 \text{ mm}$$

where

d_b = internal diameter of branch bilge suction, in mm
C = length of compartment, in metres, and
B and D are as defined in 5.1.1.

5.3 Direct bilge suctions, other than emergency suctions

5.3.1 The direct bilge suctions in the main engine room, and the direct bilge suctions in large separate boiler rooms, motor rooms of electrically propelled units and auxiliary engine rooms are not to be of a diameter less than that required for the main bilge line.

5.3.2 Where the separate machinery spaces are of small dimensions, the sizes of the direct bilge suctions to these spaces will be specially considered.

5.3.3 For sizes of emergency bilge suctions, *see* 4.6.

5.4 Main bilge line – Oil storage and similar units

5.4.1 In oil storage units, where the engine room pumps do not deal with bilge drainage outside the machinery space, the diameter of the main bilge line may be less than that required by the formula in 5.1.1, provided that the cross-sectional area is not less than twice that required for the branch bilge suctions in the machinery space.

5.5 Distribution chest branch pipes

5.5.1 The area of each branch pipe connecting the bilge main to a distribution chest is to be not less than the sum of the areas required by the Rules for the two largest branch bilge suction pipes connected to that chest, but need not be greater than that required for the main bilge line.

5.6 Tunnel suction

5.6.1 The bilge suction pipe to the tunnel well is to be not less than 65 mm bore, except in units not exceeding 60 m in length, in which case it may be 50 mm bore.

■ *Section 6*
Pumps on bilge service and their connections

6.1 Number of pumps

6.1.1 For units other than accommodation units, at least two power bilge pumping units are to be provided in the machinery space. In units of 90 m in length and under, one of these units may be worked from the main engines and the other is to be independently driven. In larger units, both units are to be independently driven.

6.1.2 Each unit may consist of one or more pumps connected to the main bilge line, provided that their combined capacity is adequate.

6.1.3 In units other than accommodation units, a bilge ejector in combination with a high pressure sea-water pump may be accepted as a substitute for an independent bilge pump, as required by 6.1.1.

6.1.4 Special consideration will be given to the number of pumps for small units and, in general, if there is a class notation restricting a small unit to harbour or river service, a hand pump may be accepted in lieu of one of the bilge pumping units.

6.1.5 For accommodation units, at least three power bilge pumps are to be provided, one of which may be operated from the main engines. Where the bilge pump numeral as derived from Regulation 35-1 of Chapter II-1 of the *International Convention for the Safety of Life at Sea, 1974*, and applicable amendments, is 30 or more, one additional independent power pump is to be provided.

6.1.6 For location of pumps on accommodation units, *see* 8.1.

6.1.7 Where the bilge pumps required by 6.1.1 or 6.1.5 are installed in spaces not fitted with a double bottom, the pumps are to be either:

(a) capable of operating in flooded spaces; or
(b) located in separate watertight compartments.

6.2 General service pumps

6.2.1 The bilge pumping units, or pumps, required by 6.1 may also be used for ballast, fire or general service duties of an intermittent nature, but they are to be immediately available for bilge duty when required, *see also* SOLAS 1974, as amended Reg. II-2/C,10, as applicable.

6.3 Capacity of pumps

6.3.1 Each bilge pumping unit, or bilge pump in the case of accommodation units, is to be connected to the main bilge line and is to be capable of giving a speed of water through the Rule size of main bilge pipe of not less than 122 m/min.

6.3.2 The capacity of each bilge pumping unit or bilge pump is to be not less than required by the following formula:

$$Q = \frac{5{,}75}{10^3} d_m^2$$

where

d_m = Rule internal diameter of main bilge line, in mm
Q = capacity, in m^3/hour.

6.3.3 In units other than accommodation units, where one bilge pumping unit is of slightly less than Rule capacity, the deficiency may be made good by an excess capacity of the other unit. In general, the deficiency is to be limited to 30 per cent.

6.4 Self-priming pumps

6.4.1 All power pumps which are essential for bilge services are to be of the self-priming type, unless an approved central priming system is provided for these pumps. Details of this system are to be submitted.

6.4.2 Cooling water pumps having emergency bilge suctions need not be of the self-priming type.

6.4.3 For requirements regarding emergency bilge suctions, *see* 4.6.

6.5 Pump connections

6.5.1 The connections at the bilge pumps are to be such that one unit may continue in operation when the other unit is being opened up for overhaul.

6.5.2 Pumps required for essential services are not to be connected to a common suction or discharge chest or pipe unless the arrangements are such that the working of any pumps so connected is unaffected by the other pumps being in operation at the same time.

6.6 Direct bilge suctions

6.6.1 The direct bilge suctions in the machinery space(s) are to be led to independent power pump(s), and the arrangements are to be such that these direct suctions can be used independently of the main bilge line suctions.

■ *Section 7*
Piping systems and their fittings

7.1 Main bilge line suctions

7.1.1 Suctions from the main bilge line, i.e. branch bilge suctions, are to be arranged to draw water from any hold, compartment, watertight section or machinery compartment of the unit, excepting small spaces such as those mentioned in 3.1.6, 3.5 and 3.6, where manual pump suctions are accepted, and are not to be of smaller diameter than that required by the formula in 5.2.1, *see also* 7.4.1 and 7.5.1. For special arrangements for oil storage tanks, *see* Chapter 15.

7.1.2 Where units, including accommodation units, are of a design having enclosed spaces located on the bulkhead deck or on the freeboard deck, special consideration will be given to the drainage arrangements where any fixed pressure water spray system is fitted, *see also* Pt 4, Ch 7,10 and 9.1.

7.2 Prevention of communication between compartments

7.2.1 The arrangement of valves, cocks and their connections is to be such as to prevent the possibility of one watertight compartment being placed in communication with another, or of machinery spaces or other dry compartments being placed in communication with the sea or with tanks. For this purpose, screw-down non-return valves are to be provided in the following fittings:

- Bilge valve distribution chests.
- Bilge suction hose connections, whether fitted directly to the pump or on the main bilge line.
- Direct bilge suctions and bilge pump connections to main bilge line.

7.3 Isolation of bilge system

7.3.1 Bilge pipes which are required for draining storage or machinery spaces are to be entirely distinct from sea inlet pipes or from pipes which may be used for filling or emptying spaces where water or oil is carried. This does not, however, exclude a bilge ejection connection, a connecting pipe from a pump to its suction valve chest, or a deep tank suction pipe suitably connected through a changeover device to a bilge, ballast or oil line.

7.4 Machinery space suctions – Mud boxes

7.4.1 Suctions for bilge drainage in machinery spaces and tunnels, other than emergency suctions, are to be led from easily accessible mud boxes fitted with straight tail pipes to the bilges and having covers secured in such a manner as to permit them to be expeditiously opened or closed. Strum boxes are not to be fitted to the lower ends of these tail pipes or to the emergency bilge suctions.

7.5 Suctions outside the machinery spaces – Strum boxes

7.5.1 The open ends of bilge suctions in storage and other compartments outside machinery spaces and tunnels, such as cofferdams and tanks other than those permanently arranged for the carriage of fresh water, water ballast, oil fuel or oil storage and for which other efficient means of pumping are provided, are to be enclosed in strum boxes having perforations of not more than 10 mm diameter, whose combined area is not less than twice that required for the suction pipe. The boxes are to be so constructed that they can be cleared without breaking any joint of the suction pipe.

7.6 Bilge wells

7.6.1 Bilge wells required by 3.2.3 and 4.2.2 are to be formed of steel plates and are to be not less than 0,15 m^3 capacity. In small compartments, steel bilge hats of reasonable capacity may be fitted.

7.6.2 In accommodation units, the depth of bilge wells in double bottom tanks will be specially considered.

7.6.3 Where access manholes to bilge wells are necessary, they are to be fitted as near to the suction strums as practicable.

7.7 Tail pipes

7.7.1 The distance between the foot of all bilge tail pipes and the bottom of the bilge well is to be adequate to allow a full flow of water and to facilitate cleaning.

7.8 Location of fittings

7.8.1 Bilge valves, cocks and mud boxes are to be fitted at, or above, the machinery space and tunnel platforms. Where it is not practicable to avoid the fittings being situated at the starting platform or in passageways, they may be situated just below the platform, provided readily removable traps or covers are fitted and nameplates indicate the presence of these fittings.

7.8.2 Where relief valves are fitted to pumps having sea connections, these valves are to be fitted in readily visible positions above the platform. The arrangements are to be such that any discharge from the relief valves will also be readily visible.

7.9 Bilge pipes in way of double bottom tanks

7.9.1 Bilge suction pipes are not to be led through double bottom tanks if it is possible to avoid doing so.

7.9.2 Bilge pipes which have to pass through these tanks are to have a wall thickness in accordance with Table 12.2.4 in Chapter 12. (The thickness of pipes made from material other than steel will be specially considered).

7.9.3 Expansion bends, not glands, are to be fitted to these pipes within the tanks, and the pipes are to be tested, after installation, to the same pressure as the tanks through which they pass.

7.10 Bilge pipes in way of deep tanks

7.10.1 In way of deep tanks, bilge pipes should preferably be led through pipe tunnels but, where this is not done, the pipes are to be of steel, having a wall thickness in accordance with Table 12.2.4 in Chapter 12, with welded joints or heavy flanged joints. The number of joints is to be kept to a minimum. The thickness of pipes made from material other than steel will be specially considered.

7.10.2 Expansion bends, not glands, are to be fitted to these pipes within the tanks.

7.10.3 The pipes are to be tested, after installation, to a pressure not less than the maximum head to which the tanks can be subjected in service.

7.11 Storage spaces – Bilge non-return valves

7.11.1 Where non-return valves are fitted to the open ends of bilge suction pipes in storage spaces in order to decrease the risk of flooding, they are to be of an approved type which does not offer undue obstruction to the flow of water.

■ *Section 8* Additional bilge drainage requirements for column-stabilised units and self-elevating units

8.1 Location of bilge pumps and bilge main

8.1.1 In accommodation units, the power bilge pumps required by 6.1.5 are to be placed, if practicable, in separate watertight compartments which will not readily be flooded by the same damage. If the engines and boilers are in two or more watertight compartments, the bilge pumps are to be distributed throughout these compartments so far as is possible. *See also* 6.1.7.

8.1.2 In accommodation units of 91,5 m or more in length, or having a bilge pump numeral of 30 or more, *see* 6.1.5 and 6.1.7, the arrangements are to be such that at least one power pump will be available for use in all ordinary circumstances in which the unit may be flooded at sea. This requirement will be satisfied if:

- one of the pumps is an emergency pump of a submersible type having a source of power situated above the bulkhead deck, or
- the pumps and their sources of power are so disposed throughout the length of the unit that, under any conditions of flooding which the unit is required by statutory regulation to withstand, at least one pump in an undamaged compartment will be available.

8.1.3 The bilge main is to be so arranged that no part is situated nearer the side of the unit than $\frac{B}{5}$, measured at right angles to the centreline at the level of the deepest subdivision load line, where B is the breadth of the unit.

8.1.4 Where any bilge pump or its pipe connection to the bilge main is situated outboard of the line $\frac{B}{5}$, a non-return valve is to be provided in the pipe connection at the junction with the bilge main. The emergency bilge pump and its connections to the bilge main are to be so arranged that they are situated inboard of the $\frac{B}{5}$ line.

8.2 Prevention of communication between compartments in the event of damage

8.2.1 Provision is to be made to prevent the compartment served by any bilge suction pipe being flooded, in the event of the pipe being severed, or otherwise damaged by collision or grounding in any other compartment. For this purpose, where the pipe is at any part situated nearer the side of the unit than $\frac{B}{5}$ or in a duct keel, a non-return valve is to be fitted to the pipe in the compartment containing the open end.

8.3 Arrangement and control of bilge valves

8.3.1 All the distribution boxes, valves and cocks in connection with the bilge pumping arrangements are to be so arranged that, in the event of flooding, one of the bilge pumps may be operative on any compartment. If there is only one system of pipes common to all pumps, the necessary valves or cocks for controlling the bilge suctions must be capable of being operated from the bulkhead deck. Where, in addition to the main bilge pumping system, an emergency bilge pumping system is provided, it is to be independent of the main system and so arranged that a pump is capable of operating on any compartment under flooding conditions; in this case, only the valves and cocks necessary for the operation of the emergency system need be capable of being operated from above the bulkhead deck.

8.3.2 All valves and cocks in 8.3.1 which can be operated from above the bulkhead deck are to have their controls at their place of operation clearly marked and provided with means to indicate whether they are open or closed.

8.4 Cross-flooding arrangements

8.4.1 Where divided deep tanks or side tanks are provided with cross-flooding arrangements to limit the angle of heel after side damage, the arrangements are to be self acting where practicable. In any case, where controls to cross flooding fittings are provided, they are to be operable from above the bulkhead deck.

Additional bilge drainage requirements for column-stabilised units and self-elevating units are given in 8.5 to 8.7.

8.5 General

8.5.1 The bilge system is to be capable of operating satisfactorily under the conditions specified in Table 1.3.2 or 1.3.3 in Chapter 1.

8.5.2 Dry compartments below the lowest continuous deck on self-elevating units, and below the main deck on column-stabilised units, containing essential equipment for the operation and safety of the unit, or providing essential buoyancy, are to have a permanently installed bilge pumping system.

8.5.3 Where the open drain pipe is carried through a watertight bulkhead or deck, it is to be fitted with an easily accessible self-closing valve at the bulkhead or deck, or a valve capable of being closed from above the damage waterline.

8.5.4 A mimic panel showing all the compartments and arrangements of the bilge and drainage systems is to be suitably positioned at the central control station.

8.6 Column-stabilised units

8.6.1 At least one of the pumps referred to in Section 6 is to be arranged solely for bilge pumping duties. This pump and the pump-room bilge suction valves are to be capable of both remote and local operation.

8.6.2 Propulsion rooms and pump-rooms in lower hulls, which are normally unattended, are to be provided with two independent systems for bilge water high level detection, providing an audible and visual alarm at the central control station.

8.6.3 Chain lockers which, if flooded, could substantially affect the unit's stability are to be provided with a remote means to detect flooding, a permanently installed means of dewatering and remote indication provided at the central control station. The dewatering system is to be independent of the main bilge system and the pumps are to have adequate reserve capacity to keep the chain locker empty in any damage condition. The minimum discharge capacity of the pumps is not to be less than the flow rate calculated using the internal diameter of the chain pipe when subjected to a head of water measured from the top of the chain pipe to the 4 m waterline defined in Pt 4, Ch 7,4.7.2.

8.7 Self-elevating units

8.7.1 The bilge system is to be arranged so that essential compartments such as machinery and pump-rooms can be emptied even when the unit is in the flooded condition. The control and position indication system for the bilge valves is to be suitable for operation if the equipment should become submerged.

8.7.2 At least one of the pumps referred to in Section 6 is to be arranged solely for bilge pumping duties.

8.7.3 Chain lockers, if fitted, may be emptied by means of portable pumps or permanently installed pumps or ejectors. Where the utilisation of portable pumps is intended, two units are to be carried on board.

■ *Section 9*
Additional requirements relating to fixed pressure water spray fire-extinguishing systems

9.1 Bilge drainage requirements

9.1.1 Where arrangements for cooling spaces below the bulkhead or freeboard deck, or fire-fighting by means of fixed spraying nozzles or by flooding of these spaces with water are provided, the following provisions are to apply, *see also* IMO guidelines (MSC.1/Circ.1320):

(a) The drainage system is to be sized to remove no less than 125 per cent of the combined capacity of both the water spraying system pumps and the required number of fire hose nozzles.
(b) The drainage system valves are to be operable from outside the protected space at a position in the vicinity of the extinguishing system controls.
(c) Adequately sized bilge wells are to be located at the side shell of the unit at a distance from each other of not more than 40 m in each watertight compartment, the bilge wells should be uniformly distributed fore and aft, *see also* Pt 3, Ch 12,4.1.4 of the Rules for Ships. For units where this is not possible, the free surface effect on the unit's stability is to be determined and submitted to the Flag Administration for appraisal.

9.1.2 If drainage of storage spaces is by gravity, the drainage is to be led directly overboard or to a closed drain tank. If led overboard, the scuppers are to comply with Pt 3, Ch 12,4.1.3. If led to a closed drain tank, this tank is to be located outside the machinery spaces and provided with a vent pipe leading to a safe location on the open deck.

9.1.3 Drainage from a storage space into bilge wells in a lower space is only permitted if that space satisfies the same requirements as the storage space above.

■ *Section 10*
Drainage arrangements for surface type units not fitted with propelling machinery

10.1 Hand pumps

10.1.1 Where auxiliary power is not provided, hand pumps are to be fitted, in number and position, as may be required for the efficient drainage of the unit.

10.1.2 In general, one hand pump is to be provided for each compartment. Alternatively, two pumps connected to a bilge main, having at least one branch to each compartment, are to be provided.

10.1.3 The pumps are to be capable of being worked from the upper deck or from positions above the load waterline which are at all times readily accessible. The suction lift is not to exceed 7,3 m and is to be well within the capacity of the pump.

10.1.4 The sizes of the hand pumps are to be not less than those given in Table 13.10.1. Where the unit is closely subdivided into small watertight compartments, 50 mm bore suctions will be accepted.

Table 13.10.1 Sizes of hand pumps

Tonnage under upper deck	Diameter of barrel of bucket pump mm	Bore of suction pipe of bucket pumps and semi-rotary pumps mm
Not exceeding 500 tons	100	50
Above 500 tons but not exceeding 1000 tons	115	57
Above 1000 tons but not exceeding 2000 tons	125	65
Above 2000 tons	140	70

10.2 Units with auxiliary power

10.2.1 In units in which auxiliary power is available on board, power pump suctions are to be provided for dealing with the drainage of tanks and of the bilges of the principal compartments.

10.2.2 The pumping arrangements are to be as required for self-propelled units, so far as these requirements are applicable, duly modified to suit the size and service of the unit.

10.2.3 Details of the pumping arrangements are to be submitted for special consideration.

■ *Section 11*
Ballast system

11.1 General requirements

11.1.1 Units are to be provided with an efficient pumping system capable of ballasting and de-ballasting any ballast tank under normal operating and transit conditions. The system is to be arranged to prevent inadvertent transfer of ballast from one tank or hull to another.

11.1.2 The ballast system is to be arranged so that it will remain operable, and tanks can be effectively de-ballasted through at least one suction, up to angles of inclination as specified in Tables 1.3.1, 1.3.2 and 1.3.3 in Chapter 1, as applicable.

11.1.3 The system is to be designed so that a single failure or mal-operation of any item of equipment or component will not lead to uncontrolled liquid movement. Pumps, piping and control systems should not be situated within the defined damage penetration zones, *see* 1.2.

11.2 Pumps

11.2.1 At least two independently driven ballast pumps are to be provided and arranged so that the system will remain operable in the event of failure of any one pump. Consideration should be given to locating the pumps in separate compartments where, in the event of flooding, fire or other damage in a particular compartment, an alternative pump in an unaffected compartment will be available. Such pumps need not be dedicated ballast pumps, but must be readily available for use on the ballast system at all times.

11.2.2 The capacity of each ballast pump is to be sufficient to provide safe handling and operation of the unit.

11.2.3 Ballast pumps should be self-priming unless it can be demonstrated that this would be unnecessary for the intended application. Pumps of the centrifugal type are to be self-priming by means of an automatic priming system.

11.3 Piping and valves

11.3.1 Ballast pipes are to be of steel or other approved material. Special consideration should be given to the design of pipes passing through tanks, particularly with regard to the effects of corrosion.

11.3.2 All valves are to be clearly marked to identify their function. Positive indication (open/closed) is to be provided at the valve, and at all positions from which the valve can be controlled. The indicators are to rely on the movement of the valve spindle.

11.3.3 The valves in the ballast system are to be self-closing by mechanical means or be power-operated by either a stored energy system provided with no fewer than two power units, or by an electrical supply system. Consideration should also be given to the need for equipment to operate when submerged.

11.3.4 The closing speed of power-operated valves should be limited where necessary, to prevent excessive pressure surges.

11.3.5 Valves which fail to set position are to be provided with an independent secondary means of closure from a readily accessible position above the damage waterplane. Power failure to sea-water inlet and discharge valves for systems such as cooling for essential machinery or for supply to fire pumps should not result in closing of open valves or in opening of closed valves. Such systems, which require the inlet/discharge valve to fail to a set position, are not to share a common inlet/discharge with systems in which the valves fail closed.

11.3.6 All sea inlet and discharge valves which are submerged at maximum operating draught and are located in normally unattended spaces are to be remotely controlled from a manned control station. Such valves are to fail automatically to the closed position on loss of control or actuating power unless overriding considerations require a valve to fail to set position.

11.4 Control of pumps and valves

11.4.1 All ballast pumps and power operated valves are to be fitted with independent local control, which may be manual control, in addition to the remote control from the central control station. The independent local control of each ballast pump and of its associated tank valves should be in the same location. Such local controls are to be readily accessible and, where practicable, their access routes should not be situated within the defined damage penetration zones, *see* 1.2. A diagram of the representative part of the ballast system is to be permanently displayed at each location.

11.4.2 The control systems are to function independently of the indicating systems, or have sufficient redundancy, such that failure of one system does not jeopardise the operation of the other systems.

11.4.3 Valves which have failed closed should, on restoration of power, remain closed until the operator assumes control of the reactivated system.

11.4.4 For requirements relating to control and supervision of unattended ballast pumps located in dangerous or hazardous spaces, *see* Pt 7, Ch 2,5.1.8.

11.5 Column-stabilised units

11.5.1 The general requirements of 11.1 to 11.4 are to be complied with unless otherwise specified in this Section.

11.5.2 The ballast system is to have the capability to bring the unit, while in an intact condition, from the maximum normal operating draught to a severe storm draught or a decrease in draught of 4,6 m, whichever distance is greater, within three hours.

11.5.3 In the damage condition, *see* Pt 4, Ch 7, the system is to have the capability of restoring the unit to a level trim and safe draught condition without taking additional ballast and with any one pump inoperable.

11.5.4 The ballast system sea-water inlets and discharges should be separate from those of other systems.

11.5.5 Ballast system manifolds are to be arranged such that a specially defined operational procedure must be carried out when ballast is transferred from one end or side of the unit to the other.

■ *Section 12* Air, overflow and sounding pipes

12.1 Definitions

12.1.1 Reference to oil fuel in this Section is to be taken to mean oil fuel which has a flash point of 60°C or above (closed-cup test).

12.2 Materials

12.2.1 Air, overflow and sounding pipes are to be made of steel or other approved material. For use of plastics pipes of approved type, *see* Chapter 12.

12.2.2 The portions of air, overflow and sounding pipes fitted above the weather deck are to be of steel or equivalent material.

12.3 Nameplates

12.3.1 Nameplates are to be affixed to the upper ends of all air and sounding pipes.

12.4 Air pipes

12.4.1 Air pipes are to be fitted to all tanks, cofferdams, tunnels and other compartments which are not fitted with alternative ventilation arrangements.

12.4.2 The air pipes are to be fitted at the opposite end of the tank to that at which the filling pipes are placed and/or at the highest part of the tank. Where the tank top is of unusual or irregular profile, special consideration will be given to the number and position of the air pipes.

12.4.3 For a normally inaccessible small void compartment such as an echo sounding compartment, which is accessed from within a normally inaccessible space such as a fore peak tank, alternative air pipe arrangements to those required by 12.4.1 may be considered. For such arrangements, a warning notice is to be located in a prominent position specifying the precautions to be taken prior to opening the manhole and entering the small void compartment. Ventilation arrangements are to be submitted to LR for approval.

12.5 Termination of air pipes

12.5.1 Air pipes to double bottom tanks, deep tanks extending to the shell plating, or tanks which can be run up from the sea are to be led to above the bulkhead deck. Air pipes to oil fuel tanks, cofferdams and all tanks which can be pumped up are to be led to the open. For height of air pipes above deck, *see* Pt 3, Ch 12,3 of the Rules for Ships.

12.5.2 Air pipes from storage tanks containing lubricating or hydraulic oil may terminate in the machinery space, provided that the open ends are so situated that issuing oil cannot come into contact with electrical equipment or heated surfaces. Air pipes from heated lubricating oil tanks are to be led to the open.

12.5.3 The open ends of air pipes to oil fuel tanks are to be situated where no danger will be incurred from issuing oil vapour when the tank is being filled.

12.5.4 The location and arrangement of air pipes for oil fuel service, settling and lubricating oil tanks are to be such that in the event of a broken vent pipe, this does not directly lead to the risk of ingress of sea-water or rainwater.

12.6 Gauze diaphragms

12.6.1 The open ends of air pipes to oil fuel tanks are to be furnished with a wire gauze diaphragm of incorrodible material which can be readily removed for cleaning or renewal.

12.6.2 Where wire gauze diaphragms are fitted at air pipe openings, the area of the opening through the gauze is to be not less than the cross-sectional area required for the pipe, *see* 12.8.

12.7 Air pipe closing appliances

12.7.1 The closing appliances fitted to tank air pipes in accordance with Pt 4, Ch 7,9 are to be of an automatic opening type which will allow the free passage of air or liquid to prevent the tanks being subjected to a pressure or vacuum greater than that for which they are designed.

12.7.2 Air pipe closing devices are to be of a type acceptable to LR and are to be tested in accordance with a National or International Standard recognised by LR. The flow characteristic of the closing device is to be determined using water, *see* 12.8.1 and 12.8.2.

12.7.3 Wood plugs and other devices which can be secured closed are not to be fitted at the outlets.

12.7.4 Air pipe automatic closing devices shall be so designed that they will withstand both ambient conditions as indicated in Pt 5, Ch 1,3.5 and 3.6 and designed working conditions, and be suitable for use at inclinations up to and including ±40°.

12.7.5 Air pipe automatic closing devices shall be constructed to allow inspection of the closure and the inside of the casing as well as changing the seals.

12.7.6 Efficient ball or float seating arrangements are to be provided for the closures. Bars, cages or other devices are to be provided to prevent the ball or float from contacting the inner chamber in its normal state, and made in such a way that the ball or float is not damaged when subjected to liquid impact due to a tank being overfilled.

12.7.7 Air pipe automatic closing devices are to be self-draining.

12.7.8 The clear area through an air pipe closing device in the open position shall be at least equal to the area of the inlet.

12.7.9 In the case of air pipe closing devices of the float type, suitable guides are to be provided to ensure unobstructed operation under all working conditions of heel and trim.

12.7.10 The maximum allowable tolerances for wall thickness of floats shall not exceed ±10 per cent of thickness.

12.7.11 The inner and the outer chambers of an automatic air pipe head are to be of a minimum thickness of 6 mm.

12.7.12 Casings of air pipe closing devices are to be of approved metallic materials, adequately protected against corrosion.

12.7.13 For galvanised steel air pipe heads, the zinc coating is to be applied by the hot method and the thickness is to be 70 to 100 microns.

12.7.14 For areas of the head susceptible to erosion (e.g. those parts directly subjected to ballast water impact when the tank is being pressed up, such as the inner chamber area above the air pipe plus an overlap of 10° or more either side), an additional harder coating should be applied. This is to be an aluminium-bearing epoxy, or other equivalent coating, applied over the zinc.

12.7.15 Closures and seats made of non-metallic materials are to be compatible with the media intended to be carried in the tank and to sea-water, and suitable for operating at ambient temperatures between –25°C and 85°C.

12.8 Size of air pipes

12.8.1 For every tank which can be filled by the unit's pumps, the total cross-sectional area of the air pipes and the design of the air pipe closing devices are to be such that when the tank is overflowing at the maximum pumping capacity available for the tank, it will not be subjected to a pressure greater than that for which it is designed.

12.8.2 In all cases, whether a tank is filled by unit's pumps or other means, the total cross-sectional area of the air pipes is to be not less than 25 per cent greater than the effective area of the respective filling pipe.

12.8.3 For each ballast tank of column-stabilised units, air pipes of sufficient size and number are to be provided to permit the efficient operation of the ballast pumping system under conditions referred to in 11.5. To allow de-ballasting of tanks intended to be used to bring the unit back to normal draught, and to ensure no inclination after damage, air pipe openings are to be above the worst damage waterline, and positioned outside the defined damage penetration zones, *see* Pt 4, Ch 7,4.

12.8.4 Where tanks are fitted with cross-flooding connections, the air pipes are to be of adequate area for these connections.

12.8.5 Air pipes are to be not less than 50 mm bore.

12.9 Overflow pipes

12.9.1 For all tanks which can be filled by the unit's pumps or by pumps from an external source, overflow pipes are to be fitted where:

(a) The total cross-sectional area of the air pipe is less than that required by 12.8.
(b) The pressure head corresponding to the height of the air pipe is greater than that for which the tank is designed.

12.9.2 Overflow pipes from tanks, other than oil fuel and lubricating oil tanks, are to be led to the open deck and fitted with closing appliances in accordance with 11.7, *see also* Pt 4, Ch 7.

12.9.3 In the case of oil fuel and lubricating oil tanks, the overflow pipe is to be led to an overflow tank of adequate capacity or to a storage tank having a space reserved for overflow purposes. These overflow tanks are to have a capacity large enough to take an overflow for 10 minutes at the normal filling rate. Suitable means are to be provided to indicate when an overflow is occurring, or when the contents reach a predetermined level in the tanks.

12.9.4 Overflow pipes are to be self-draining under normal conditions of trim.

12.9.5 Where overflow sight glasses are provided, they are to be in a vertically dropping line and designed such that the oil does not impinge on the glass. The glass is to be of heat-resisting quality, adequately protected from mechanical damage and well lit.

12.10 Air and overflow systems

12.10.1 Where a combined air or overflow system is fitted, the arrangement is to be such that, in the event of any one of the tanks being bilged, tanks situated in other watertight compartments of the unit cannot be flooded from the sea through combined air pipes or the overflow main. For this purpose, it will normally be necessary to lead the overflow pipe to a point close to the bulkhead deck.

12.10.2 Where overflow from tanks which are used for the alternative carriage of oil and water ballast is connected to an overflow system, arrangements are to be made to prevent water ballast overflowing into tanks containing oil, *see also* Ch 14,4.14.

12.10.3 Where a common overflow main is provided, the main is to be sized to allow any two tanks connected to that main to overflow simultaneously.

12.11 Sounding arrangements

12.11.1 Provision is to be made for sounding all tanks and the bilges of those compartments which are not at all times readily accessible. The soundings are to be taken as near the suction pipes as practicable. Where a remote level indicating system is used, an additional sounding system is to be provided.

12.11.2 Ballast tanks of column-stabilised units are to be provided with sounding pipes or other suitable sounding devices which are separate and additional to any remote sounding systems. The soundings are to be taken as near to the suction pipes as practicable. Where remote sounding systems are fitted, the indications are to be located in the central control station.

12.11.3 Dry compartments located below the waterline are to be provided with individual leak detection devices which have their indication in the central control station.

12.11.4 Bilges of compartments which are not at all times readily accessible are to be provided with sounding pipes.

12.11.5 Where fitted, sounding pipes are to be as straight as practicable, and if curved to suit the structure of the unit, the curvature must be sufficiently easy to permit the ready passage of the sounding rod or chain.

12.11.6 Sounding devices of approved type may be used in lieu of sounding pipes for sounding tanks. These devices are to be tested, after fitting on board, to the satisfaction of the Surveyors.

12.11.7 Where gauge glasses are used for indicating the level of liquid in tanks containing lubricating oil, oil fuel or other flammable liquid, the glasses are to be of the flat type of heat-resisting quality, adequately protected from mechanical damage, and fitted with self-closing valves at the lower ends and at the top ends if these are connected to the tanks below the maximum liquid level.

12.11.8 If means of sounding, other than a sounding pipe, are fitted in any unit for indicating the level of liquid in tanks containing oil fuel, lubricating oil or other flammable liquid, failure of such means or over-filling of the tank should not result in the release of tank contents.

12.11.9 In accommodation units, sounding devices for oil fuel tanks, lubricating oil tanks and other tanks which may contain flammable liquids are to be of a type which does not require penetration below the top of the tank.

12.11.10 For a normally inaccessible small void compartment such as an echo sounding compartment, which is accessed from within a normally inaccessible space such as a fore peak tank, alternative sounding arrangements to those required by 12.11.1 may be considered. For such arrangements, a warning notice is to be located in a prominent position specifying precautions to be taken prior opening the manhole of the small void compartment. Means are to be provided to indicate flooding of the compartment without opening, such as fitting indicator plugs to the manhole. Sounding arrangements are to be submitted to LR for approval.

12.12 Termination of sounding pipes

12.12.1 Sounding pipes are to be led to positions above the bulkhead deck which are at all times accessible and, in the case of oil fuel tanks, storage oil tanks, lubricating oil tanks and tanks containing other flammable oils, the sounding pipes are to be led to safe positions on the open deck.

12.12.2 Sounding pipes are to be provided with permanently attached means of closing to prevent entry of water. *See also* Pt 4, Ch 7.

12.12.3 For closing requirements, *see also* Pt 4, Ch 7,9.

12.13 Short sounding pipes

12.13.1 In machinery spaces and tunnels, in circumstances where it is not practicable to extend the sounding pipes as mentioned in 12.12, short sounding pipes extending to well lighted readily accessible positions above the platform may be fitted to double bottom tanks. Where such pipes serve tanks containing oil fuel or other flammable liquid, an additional sounding device of approved type is to be fitted. An additional sounding device is not required for lubricating oil tanks. Any proposal to terminate in the machinery space, sounding pipes to tanks other than double bottom tanks, will be the subject of special consideration.

12.13.2 Short sounding pipes to oil fuel (flash point not less than 60°C), lubricating oil tanks and other flammable oil tanks (flash point not less than 60ºC) are to be fitted with cocks having parallel plugs with permanently attached handles, so loaded that, on being released, they automatically close the cocks. In addition, a small diameter self-closing test cock is to be fitted below the cock mentioned above in order to ensure that the sounding pipe is not under a pressure of oil before opening up the sounding cock. Provision is to be made to ensure that discharge of oil through this test cock does not present an ignition hazard. An additional small diameter self-closing test cock is not required for lubricating oil tanks.

12.13.3 As a further precaution against fire, such sounding pipes are to be located in positions as far removed as possible from any heated surface or electrical equipment and, where necessary, effective shielding is to be provided in way of such surfaces and/or equipment.

12.13.4 In units that are required to be provided with a double bottom, short sounding pipes, where fitted to double bottom tanks, are in all cases to be provided with self-closing cocks as described in 12.13.2.

12.13.5 Where a double bottom is not required to be fitted, short sounding pipes to tanks other than oil tanks are to be fitted with shut-off cocks or with screw caps attached to the pipes by chains.

12.13.6 In accommodation units, short sounding pipes are permissible only for sounding cofferdams and double bottom tanks situated in a machinery space, and are in all cases to be fitted with self-closing cocks as described in 12.13.2.

12.14 Elbow sounding pipes

12.14.1 Elbow sounding pipes are not to be used for deep tanks unless the elbows and pipes are situated within closed cofferdams or within tanks containing similar liquids. They may, however, be fitted to other tanks and may be used for sounding bilges, provided that it is not practicable to lead them direct to the tanks or compartments, and subject to any subdivision and damage stability requirements that may apply, *see* 1.2.1.

12.14.2 The elbows are to be of heavy construction and adequately supported.

12.14.3 In accommodation units, elbow sounding pipes are not permissible.

12.15 Striking plates

12.15.1 Striking plates of adequate thickness and size are to be fitted under open-ended sounding pipes.

12.15.2 Where slotted sounding pipes having closed ends are employed, the closing plugs are to be of substantial construction.

12.16 Sizes of sounding pipes

12.16.1 Sounding pipes are to be not less than 32 mm bore.

12.16.2 All sounding pipes, whether for compartments or tanks, which pass through refrigerated spaces or the insulation thereof, in which the temperatures contemplated are 0°C or below, are to be not less than 65 mm bore, *see also* 2.8.1 for insulation.

■ *Cross-references*

For 'Ice Class' requirements, *see* Part 8 of the Rules for Ships.

For venting and gauging equipment for cargo tanks in oil storage units, *see* Ch 15.4 and Ch 15.5.

For control engineering equipment, *see* Pt 6, Ch 1.

For requirements relating to scuppers and sanitary discharges, *see* Pt 3, Ch 12 of the Rules for Ships and Pt 4, Ch 7.

■ *Section 13*
Water ingress detection arrangements

13.1 General requirements

13.1.1 Flooding detection systems in accommodation units carrying 36 persons or more are to be fitted in accordance with the requirements of SOLAS 1974 as amended, Chapter II-1, Regulation 22-1.

13.1.2 Alarm and indicators specified in 13.2 to 13.4 are to be provided on the navigation bridge and, for accommodation units, additionally in the safety centre if located in a separate space from the navigation bridge.

13.1.3 Equipment required by 13.1.2 to 13.1.4 is to satisfy the applicable requirements of Pt 6, Ch 1.

13.1.4 Pt 6, Ch 1,1.3.1 details applicable requirements for Survey at the manufacturer's works. At the initial installation and during each subsequent Complete Survey of Machinery alarm systems or Special Survey, the operation of the ingress detection arrangements is to be demonstrated to the satisfaction of the LR Surveyor.

13.1.5 Where alternative arrangements to those required by 13.1.2 to 13.1.4 are proposed, evidence is to be submitted for consideration by LR that demonstrates:

- water ingress will be detected in all areas considered necessary reliably to detect flooding of watertight spaces;
- responsible personnel will be effectively notified in the event of water ingress to allow for planned response; and
- acceptance by the National Administration with which the unit is registered.

13.2 Flooding detection systems in accommodation units

13.2.1 Accommodation units for 36 persons or more are to be provided with a flooding detection system for watertight spaces below the bulkhead deck.

13.2.2 The flooding detection system required by 13.2.1 is to be fitted in all watertight spaces below the bulkhead deck that:

(a) have a volume, in cubic metres, that is more than the unit's moulded displacement per centimetre immersion at deepest subdivision draught; or

(b) have a volume more than 30 cubic metres, whichever is the greater.

13.2.3 Any watertight spaces that are individually equipped with a liquid level monitoring system (such as fresh water, ballast water, fuel, etc.), including an indicator panel or other means of monitoring at the navigation bridge, and the safety centre if located in a separate space from the navigation bridge, are excluded from the requirements of this sub-Section.

13.2.4 The number and location of flooding detection sensors is to be sufficient to ensure that any substantial water ingress into a watertight space requiring a flooding detection system is detected under reasonable angles of trim and heel. To accomplish this, flooding detection sensors are to be installed as indicated below:

(a) **Vertical location** – sensors are to be installed as low as practical in the watertight space;

(b) **Longitudinal location** – in watertight spaces located forward of the mid-length, sensors are generally to be installed at the forward end of the space; in watertight spaces located aft of the mid-length, sensors are generally to be installed at the aft end of the space. For watertight spaces located in the vicinity of the mid-length, consideration is to be given to the appropriate longitudinal location of the sensor. In addition, any watertight space of length more than 20 per cent of the unit's subdivision length or with arrangements that would seriously restrict the longitudinal flow of water is to be provided with sensors at both the forward and aft ends; and

(c) **Transverse location** – sensors are generally to be installed at the centreline of the space (or alternatively at both the port and starboard sides). In addition, any watertight space that extends the full breadth of the unit or with arrangements that would seriously restrict the transverse flow of water is to be provided with sensors at both the port and starboard sides.

13.2.5 Where a watertight space extends in height over more than one deck, there is to be at least one flooding detection sensor at each deck level. This provision is not applicable in cases where a continuous flood level monitoring system is installed.

13.2.6 Consideration may be given to the number and location of flooding detection sensors in watertight spaces with unusual arrangements or in other cases where these requirements would not achieve the intended purpose, *see* 13.1.5.

Section

■ *Section 1*
General requirements

1.1 General

1.1.1 In addition to the requirements detailed in this Chapter, the requirements of Ch 13,1 and 2 are to be complied with, where applicable.

1.1.2 The requirements of Ch 13,3 are also to be complied with, so far as they are applicable, for the drainage of tanks, oily bilges and cofferdams, etc.

1.1.3 The requirements of Sections 2 and 4 are to be complied with, as far as they are applicable, for all flammable liquids.

■ *Section 2*
Oil fuel – General requirements

2.1 Flash point

2.1.1 The flash point (closed-cup test) of oil fuel for use in units classed for unrestricted service is, in general, to be not less than 60°C. For emergency generator engines a flash point of not less than 43°C is permissible.

2.1.2 The use of oil fuel having a flash point of less than 60° but not less than 43° may be permitted for emergency generators, emergency fire pumps, engines and auxiliary machines which are not located in machinery spaces subject to the requirements of 4.19.

2.1.3 The use of fuel having a lower flash point than specified in 2.1.1 or 2.1.2 may be permitted in units provided that such fuel is not stored in any machinery space and the arrangements for the complete installation are specially approved.

2.1.4 In general, oil fuel in storage and service tanks is not to be heated to a temperature exceeding 10°C below its flash point. Higher temperatures will be considered where:

(a) The tanks are vented to a safe position outside the engine room and, as in the case of all oil fuel tanks, the ends of the ventilation pipes are fitted with gauze diaphragms.

(b) Openings in the drainage systems of tanks containing heated oil fuel are located in spaces where no accumulation of oil vapours at temperatures close to the flash point can occur.

(c) There is no source of ignition in the vicinity of the ventilation pipes or near the openings in the drainage systems or in the tanks themselves.

2.1.5 The temperature of any heating medium is not to exceed 220°C.

2.2 Special fuels

2.2.1 When it is desired to carry a quantity of fuel having a flash point below 43°C for special services, e.g., aviation spirit for use in helicopters, full particulars of the proposed arrangements are to be submitted for special consideration. For helicopter refuelling, as a minimum, the requirements of SOLAS 1974 as amended II-2/G, 18-7 will apply.

2.2.2 For the burning of methane gas, *see the Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquefied Gases in Bulk* (hereinafter referred to as the Rules for Ships for Liquefied Gases).

2.2.3 Where it is proposed to use gaseous fuels for main or auxiliary engines, the relevant requirements of the Rules for Ships for Liquefied Gases are to be complied with. Full particulars of the proposed arrangements are to be submitted for special consideration. Attention is to be given to any relevant statutory requirements of the National Authority of the country in which the units are to be registered.

2.3 Oil fuel sampling

2.3.1 Sampling points are to be provided at locations within the oil fuel system that enable samples of oil fuel to be taken in a safe manner.

2.3.2 The position of a sampling point is to be such that the sample of the oil fuel is representative of the oil fuel quality at that location within the system.
NOTE
Samples taken from sounding pipes are not considered to be representative of the tank's contents.

2.3.3 The sampling arrangements within the machinery space are to be capable of safely providing samples when machinery is running and are to be provided with isolating valves and cocks of the self-closing type. The sampling points are to be located in positions as far removed as possible from any heated surface or electrical equipment so as to preclude impingement of oil fuel onto such surfaces on equipment under all operating conditions, *see* Ch 1,3.7.

2.4 Ventilation

2.4.1 The spaces in which the oil fuel burning appliances and the oil fuel settling and service tanks are fitted are to be well ventilated and easy of access.

2.5 Boiler insulation and air circulation in boiler room

2.5.1 The boilers are to be suitably lagged. The clearance spaces between the boilers and tops of the double bottom tanks, and between the boilers and the sides of the storage tanks in which oil fuel is carried, are to be adequate for the free circulation of the air necessary to keep the temperature of the stored oil sufficiently below its flash point.

2.5.2 Where water tube boilers are installed, there is to be a space of at least 760 mm between the tank top and the underside of the pans forming the bottom of the combustion spaces.

2.5.3 Smoke-box doors are to be shielded and well fitting, and the uptake joints made gastight. Where the surface temperature of the uptakes may exceed 220°C, they are to be efficiently lagged to minimise the risk of fire and to prevent damage by heat. Where lagging covering the uptakes, including flanges, is oil-absorbing or may permit penetration of oil, the lagging is to be encased in sheet metal or equivalent. In locations where the Surveyor is satisfied that oil impingement could not occur, the lagging need not be encased.

2.6 Funnel dampers

2.6.1 Dampers which are capable of completely closing the gas passages are not to be fitted to inner funnels of units equipped for burning oil fuel only.

2.7 Heating arrangements

2.7.1 Where steam is used for heating oil fuel, oil storage or lubricating oil, in bunkers, tanks, heaters or separators, the exhaust drains are to discharge the condensate into an observation tank in a well lighted and accessible position where it can be readily seen whether or not it is free from oil, *see* Ch 15,6.3.

2.7.2 Where hot water is used for heating, means are to be provided for detecting the presence of oil in the return lines from the heating coils.

2.7.3 Where it is proposed to use any heating medium other than steam or hot water, full particulars of the proposed arrangements are to be submitted for special consideration.

2.7.4 The heating pipes in contact with oil are to be of iron, steel, approved aluminium alloy or approved copper alloy, and, after being fitted on board, are to be tested by hydraulic pressure in accordance with the requirements of Ch 12,8.1.

2.7.5 Where electric heating elements are fitted, means are to be provided to ensure that all elements are submerged at all times when electric current is flowing and that their surface temperature cannot exceed 220°C.

2.8 Temperature indication

2.8.1 Tanks and heaters in which oil is heated are to be provided with suitable means for ascertaining the temperature of the oil. Where thermometers or temperature sensing devices are not fitted in blind pockets, a warning notice, in raised letters, is to be affixed adjacent to the fittings stating 'Do not remove unless tank/heater is drained'.

2.8.2 Controls are to be fitted to limit oil temperatures in oil storage and service tanks in accordance with 2.1.4 and in oil heaters to the maximum approved operating temperature, *see* Pt 6, Ch 1.

2.9 Precautions against fire

2.9.1 Additional requirements with respect to unit types as indicated in this Section are also to be complied with as applicable.

2.9.2 For requirements relating to arrangements for the burning of fuel gas or crude oil/slops, *see* Chapter 16.

2.9.3 Where boilers or machinery units are fuelled by gas or crude oil/slops, the enclosed spaces in which they are installed are to be specially ventilated, *see* Ch 16,1.5.

2.9.4 Fired boilers and other fired units are not to be installed in hazardous areas, but where this cannot be avoided, installation may be permitted in a Zone 2 hazardous area provided that adequate precautions have been taken against the risk of dangerous ignition.

2.9.5 Internal combustion engines are not to be installed in hazardous areas, but where this cannot be avoided, suitably protected engines may be permitted in a Zone 2 hazardous area provided the arrangements comply with the requirements of Pt 7, Ch 2,7.

2.9.6 Exhaust outlets of internal combustion engines (unless certified for use as a mobile engine in a Zone 2 hazardous area, *see* Pt 7, Ch 2,7), fired boilers and other fired units are to discharge outside hazardous areas. Exhaust outlets of internal combustion engines are to be suitably insulated and fitted with efficient spark arresters.

2.9.7 Exhaust pipes are not to be led in the vicinity of tanks containing flammable fluids, switchboards or electrical appliances.

2.9.8 Exhaust gases are to be discharged so that they will not endanger personnel or create a danger during helicopter operations.

2.9.9 Where units are intended to operate in cold climates, or where low temperatures are expected in process plant and equipment, suitable means of heating to maintain the process plant and equipment in operation are to be provided.

2.9.10 Electric heating elements are to be fitted with automatic temperature control, a high temperature alarm and an independent sensor and cut-out with manual reset. Where the elements are self-regulating and are limited to temperatures below 200°C, the independent sensor and cut-out may be omitted. For electric elements heating fluids in bunkers, tanks, heaters or separators, means are to be provided to ensure that they are submerged at all times when the current is flowing, by provision of a low-level sensor to cut off the power supply at a level above that at which the heating element would be exposed.

2.9.11 *See also* Section 13 for alarm requirements for unattended tanks and heaters.

2.9.12 Where daily service oil fuel tanks are filled automatically or by remote control, means should be provided to prevent overflow spillage through the air pipe. Other equipment such as oil fuel purifiers and heaters which treats flammable fluids automatically should have arrangements to prevent overflow spillage and, wherever practicable, should be installed in a special space reserved for such equipment. *See* Ch 13,12 regarding the termination of air pipes.

2.9.13 Oil fuel tanks and oil fuel filters are not to be situated immediately above boilers or other highly heated surfaces, *see also* Ch 1,4.5.

2.9.14 Oil fuel pipes are not to be installed above or near high temperature equipment. Oil fuel pipes should also be installed and screened or otherwise suitably protected to avoid oil spray or oil leakages onto hot surfaces, into machinery air intakes, or other sources of ignition such as electrical equipment. Pipe joints are to be kept to a minimum, and where provided are to be of a type acceptable to LR. Pipes are to be led in well lit and readily visible positions, *see also* Ch 2,7.

2.9.15 Pumps, filters and heaters are to be located to avoid oil spray or oil leakages onto hot surfaces or other sources of ignition, or onto rotating machinery parts. Where necessary, shielding is to be provided and the arrangements are to allow easy access for routine maintenance. The design of filter and strainer arrangements is to be such as to avoid the possibility of them being opened inadvertently when under pressure. This may be achieved by either mechanically preventing the pressurised filter from being opened or by providing pressure gauges which clearly indicate which filter is under pressure. In either case, suitable means for pressure release are to be provided, with drain pipes led to a safe location.

2.9.16 The arrangement and location of short sounding pipes to oil tanks are to be in accordance with Ch 13,12.13. For alternative sounding arrangements, *see* Ch 13,12.11.

2.9.17 Water service pipes and hoses are to be fitted in order that the floor plates and tank top or shell plating in way of boilers, oil fuel apparatus or deep storage tanks in the engine and boiler spaces can at any time be flushed with sea-water.

2.9.18 So far as is practicable, the use of certain plastics and wood is to be avoided in the engine rooms, boiler rooms and tunnels of units burning oil fuel.

2.9.19 Drip trays are to be fitted at the furnace mouths to intercept oil escaping from the burners, and under all other oil fuel appliances which are required to be opened up frequently for cleaning or adjustment.

2.9.20 Oil-tight drip trays of ample size having suitable drainage arrangements are to be provided at pipes, pumps, valves and other fittings where there is a possibility of leakage. Valves should be located in well lighted and readily visible positions. Drip trays will not be required where pumps, valves and other fittings are placed in special compartments either inside or outside the machinery space with approved overall drainage arrangements or for valves which are so positioned that any leakage will drain directly into the bilges *see* 2.9.2.

2.9.21 Where drainage arrangements are provided from collected leakages, they are to be led to a suitable oil drain tank not forming part of an overflow system.

2.9.22 Separate oil fuel tanks are to be placed in an oil-tight spill tray of ample size having drainage arrangements leading to a drain tank of suitable size, *see* 4.17.

2.10 Oil fuel contamination

2.10.1 The materials and/or their surface treatment used for the storage and distribution of oil fuel are to be selected such that they do not introduce contamination or modify the properties of the fuel. The use of copper or zinc compounds in oil fuel distribution and utilisation piping is not permitted except for small diameter pipes in low pressure systems, *see* 4.6.1.

2.10.2 For prevention of ingress of water into oil fuel tanks via air pipes, *see* Pt 5, Ch 13,10.5.4 of the Rules for Ships.

2.10.3 The piping arrangements for oil fuel are to be separate and distinct from those intended for lubricating oil systems to prevent contamination of fuel oil by lubricating oil.

2.10.4 The piping arrangements for gas oil, distillate and diesel grades are to be separate and distinct from those intended for residual grades, up to the service tanks required by 4.18, to prevent cross-contamination. Cross-connection is permitted between separate arrangements in the event of failure of a designated item of equipment.

2.11 Tanks and cofferdams

2.11.1 Tanks containing oil fuel are to be separated from personnel, crew and baggage compartments by a gastight and watertight boundary or a cofferdam which is suitably ventilated and drained.

■ *Cross-reference*

For requirements regarding refrigerated cargo spaces in way of oil storage tanks, *see* Pt 6, Ch 3,4 of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships).

■ *Section 3*
Oil fuel burning arrangements

3.1 Oil burning units

3.1.1 All oil burning equipment is to be capable of operating at defined power/rating levels where specified by the Owner/Operator. Confirmation by the manufacturer of this capability is to be provided to LR including the specified power/rating parameters, and operating and maintenance regimes. *See also* Pt 5, Ch 1,3.1.2.

3.1.2 Where steam is required for the main propelling engines, or where steam or thermal oil is required for auxiliary machinery for essential services, or for heating of heavy oil fuel and is generated by burning oil fuel under pressure, there are to be not less than two oil burning units. For auxiliary boilers, a single oil burning unit may be accepted, provided that alternative means, such as an exhaust gas boiler or composite boiler, are available for supply of essential services. Where the oil burning unit is not of the monobloc type (i.e., separate register and oil supply unit), each oil burning unit is to comprise a pressure pump, suction filter, discharge filter and, when required, a heater.

3.1.3 In installations consisting of two or more oil burning units, the number, arrangement and capacity of such units is to be capable of supplying sufficient fuel to allow the steam to be generated or thermal oil heated, as applicable to provide essential services with any one unit out of action.

3.1.4 Unit pressure pumps are to be entirely separate from the feed, bilge or ballast systems.

3.1.5 In dual oil fuel burning systems for boilers which are primarily designed for operation with residual fuel oil grades, arrangements are to be such that atomising steam cannot be used in combination with distillate fuel oil grades where the burner arrangements have not been designed for such use.

3.1.6 In all dual oil fuel burning systems for boilers, the manufacturer of the combustion equipment is to ensure that the full system, including control and monitoring systems, is capable of continuous operation in all conditions for each fuel grade.

3.1.7 Whenever the oil fuel burning units are stopped, shut-off arrangements for oil fuel to the units are to be provided as follows:

(a) If the supply oil fuel is under pressure during shut-off to oil burning units, duplicated shut-off valves in series are to be fitted. Arrangements are to be such as to allow manual testing for leakage from each of the valves in the installed condition, the test arrangement is to be such as to prevent inadvertent operation, and any discharges are to be led to a safe position to ensure that discharge of leakage oil does not present an ignition hazard.

(b) If arrangements are such that oil fuel pressure is released through drainage during oil fuel shut-off to oil burning units, a single shut-off device may be accepted subject to approval by LR.

3.1.8 When combined air and fuel/steam/air combustion systems are used for multiple boiler installations, they are to be such that single boiler operation will not be adversely affected by the operation of another boiler system at any time.

3.1.9 Arrangements are to be such that furnace prepurging is completed prior to any burner ignition sequence. The purge time is to be based on a minimum of 4 air changes of the combustion chamber, furnace and uptake spaces. The purge timing is to take account of the air flow rate and the sequence is not to commence until all air registers and dampers, as applicable, are fully open and the forced draught fans are operating.

3.1.10 The effect of multiple light-off failures is to be assessed and the need to lock out further ignition sequences established. The manufacturer's recommended procedures are to be followed before further attempts to ignite the boiler are made. These procedures are to be displayed at the ignition control positions and included in the warning notice required by 3.1.11.

3.1.11 Means are to be provided so that, in the event of flame failure, the oil fuel supply to the burner(s) is shut off automatically, and an alarm is given.

3.1.12 It is to be demonstrated to the Surveyor's satisfaction during trials that burner shut-off times due to flame failure comply with the following requirements, and details of the procedures and means used to set this time interval are to be submitted for consideration:

(a) The time interval at burner start-up between the burner oil fuel valve(s) being opened and then closed in the event of flame failure is to be long enough to allow a stable flame to be established and detected under normal operational circumstances, but is to be set to minimise the quantity of oil fuel delivered to the furnace and the possibility of subsequent damage as a result of unintended ignition.

(b) The time interval between flame failure detection and closing of burner oil fuel valve(s) is to be long enough to prevent shut-down due to incorrect detection of a flame failure under normal operational circumstances, but is to be set to minimise the quantity of unburned oil fuel delivered to the furnace and the possibility of subsequent damage as a result of unintended ignition.

3.1.13 A warning notice is to be fitted in a prominent position at every oil burning unit local manual control station which specifies that burners operated with manual or local overrides in use are only to be ignited after sufficient purging of the furnace and of any additional precautions required when operating in this condition.

3.2 Gravity feed

3.2.1 In systems where oil is fed to the burners by gravity, duplex filters are to be fitted in the supply pipeline to the burners and so arranged that one filter can be opened up when the other is in use.

3.3 Starting-up unit

3.3.1 A starting-up oil fuel unit, including an auxiliary heater and hand pump, or other suitable starting-up device, which does not require power from shore, is to be provided.

3.3.2 Alternatively, where auxiliary machinery requiring compressed air or electric power is used to bring the boiler plant into operation, the arrangements for starting such machinery are to comply with Ch 2,8.11.

3.4 Steam connections to burners

3.4.1 Where burners are provided with steam purging and/or atomising connections, the arrangements are to be such that oil fuel cannot find its way into the steam system in the event of valve leakage.

3.5 Burner arrangements

3.5.1 The burner arrangements are to be such that a burner cannot be withdrawn unless the oil fuel supply to that burner is shut off, and that the oil cannot be turned on unless the burner has been correctly coupled to the supply line.

3.6 Quick-closing valve

3.6.1 A quick-closing master valve is to be fitted to the oil supply to each boiler manifold, suitably located so that the valve can be readily operated in an emergency, either directly or by means of remote control, having regard to the machinery arrangements and location of controls.

3.7 Spill arrangements

3.7.1 Provision is to be made, by suitable non-return arrangements, to prevent oil from spill systems being returned to the burners when the oil supply to these burners has been shut off.

3.8 Alternately fired furnaces

3.8.1 For alternately fired furnaces of boilers using exhaust gases and oil fuel, the exhaust gas inlet pipe is to be provided with an isolating device and interlocking arrangements whereby oil fuel can only be supplied to the burners when the isolating device is closed to the boiler.

3.9 Oil fuel treatment for supply to main and auxiliary oil engines and gas turbines

3.9.1 A suitable fuel treatment plant that may include filtration, centrifuging and/or coalescing is to be provided to reduce the level of water and particulate contamination of the oil fuel to within the engine or gas turbine manufacturer's limits for inlet to the combustion system. The capacity and arrangements of the treatment plant are to be suitable for ensuring availability of treated oil fuel for the maximum continuous demand of the propulsion and electrical generating plant.

3.9.2 Two or more treatment systems are to be provided as part of the fuel treatment plant such that failure of one system will not render the other system(s) inoperative. Arrangements are to ensure that the failure of a treatment system will not interrupt the supply of clean oil fuel to oil engines or gas turbines used for propulsion and electrical generating purposes where treatment plant is installed between oil fuel service tanks and the inlet to the combustion system. Any treatment equipment in the system is to be capable of being cleaned without interrupting the flow of treated fuel to supply the combustion system.

3.9.3 Centrifuges used for oil fuel treatment are to be type tested for their intended usage when installed on board a unit in accordance with a standard acceptable to LR.

3.9.4 Where heating of the oil fuel is required for the efficient functioning of the oil fuel treatment plant, a minimum of two heating units are to be provided. Each heating unit is to be of sufficient capacity to raise and maintain the required temperature of the oil fuel for the required delivery flow rate.

3.9.5 Heating units may be in circuit with separate treatment systems or provided with connections such that any heating unit can be connected to any treatment system.

3.9.6 Where heating of the oil fuel is required for combustion, no fewer than two pre-heaters are to be provided, each with sufficient capacity to raise the temperature of the fuel to provide a viscosity suitable for combustion.

3.9.7 Filters and/or coalescers are to be fitted in the oil fuel supply lines to each oil engine and gas turbine to ensure that only suitably filtered oil is fed to the combustion system. The arrangements are to be such that any unit can be cleaned without interrupting the supply of filtered oil to the combustion system.

3.10 Booster pumps

3.10.1 Where an oil fuel booster pump is fitted, which is essential to the operation of the main engine, a standby pump is to be provided.

3.10.2 The standby pump is to be connected ready for immediate use but where two or more main engines are fitted, each with its own pump, a complete spare pump may be accepted provided that it is readily accessible and can easily be installed.

3.11 Fuel valve cooling pumps

3.11.1 Where pumps are provided for fuel valve cooling, the arrangements are to be in accordance with 3.10.

3.12 Oil-fired galleys

3.12.1 The oil fuel tank is to be located outside the galley and is to be fitted with approved means of filling and venting.

3.12.2 The fuel supply to the burners is to be controlled from a position which will always be accessible in the event of a fire occurring in the galley.

3.12.3 The galley is to be well ventilated.

3.12.4 When liquefied petroleum gas is used, bottles are to be stored on the open deck or in a well ventilated space which only opens to the open deck.

3.13 Fire and safety arrangements

3.13.1 The general requirements for oil fuel are given in Pt 5, Ch 15,2, which are to be complied with where applicable.

3.13.2 Additional requirements with respect to unit types as indicated in this Section are also to be complied with as applicable.

3.13.3 The use of oil fuels of flash point lower than 43°C closed-cup test will require special consideration of storage, handling facilities and controls, as well as the electrical installation and ventilation provisions.

3.13.4 In general, oil fuel in storage and service tanks is not to be heated to a temperature exceeding 10°C below its flash point. Higher temperatures will be considered where:

- the tanks are vented to a safe location outside the storage spaces and the ventilation pipes are fitted with an approved type of vent head with flame arrester;
- a high temperature alarm is fitted if the flash point of the oil fuel could be exceeded.

3.13.5 When aviation fuel of flash point lower than 43°C closed-cup test is carried, full particulars of the proposed arrangements are to be submitted. Fuel which has a flash point below 37°C is not permitted. The fuel specification is to comply with National Authority Regulations.

3.13.6 For requirements relating to arrangements for the burning of fuel gas or crude oil/slops, *see* Chapter 16.

3.13.7 Where boilers or machinery units are fuelled by gas or crude oil/slops, the enclosed spaces in which they are installed are to be specially ventilated, *see* Ch 16,1.5.

3.13.8 Clearance spaces between boilers and decks and between boilers and oil fuel storage tanks are to be adequate for the unimpeded circulation of air necessary to maintain the temperature of the stored fuel sufficiently below its flash point.

3.13.9 Where watertube boilers are installed there is to be an air circulation space of at least 760 mm between the deck and the underside of the pans forming the bottom of the combustion spaces.

3.13.10 Fired boilers and other fired units are not to be installed in hazardous areas, but where this cannot be avoided, installation may be permitted in a Zone 2 hazardous area provided that adequate precautions have been taken against the risk of dangerous ignition.

3.13.11 Internal combustion engines are not to be installed in hazardous areas, but where this cannot be avoided, suitably protected engines may be permitted in a Zone 2 hazardous area provided the arrangements comply with the requirements of Pt 7, Ch 2,7.

3.13.12 Boilers and other fired units are to be suitably lagged. Smokebox doors are to be shielded and well-fitting and the uptake joints made gastight. Where the surface temperature of the uptakes could exceed 200°C they are to be efficiently lagged to minimise the risk of fire and to prevent damage by heat. Where lagging covering the uptakes, including flanges, is oil-absorbing or could permit oil penetration, it is to be encased in sheet metal or equivalent. In locations where the Surveyor is satisfied that oil impingement cannot occur, the lagging need not be encased. *See also* Section 14.

3.13.13 Exhaust outlets of internal combustion engines (unless certified for use as a mobile engine in a Zone 2 hazardous area, *see* Pt 7, Ch 2,7), fired boilers and other fired units are to discharge outside hazardous areas. Exhaust outlets of internal combustion engines are to be suitably insulated and fitted with efficient spark arresters.

3.13.14 Exhaust pipes are not to be led in the vicinity of tanks containing flammable fluids, switchboards or electrical appliances.

3.13.15 Exhaust gases are to be discharged so that they will not endanger personnel or create a danger during helicopter operations.

3.13.16 Where units are intended to operate in cold climates, or where low temperatures are expected in process plant and equipment, suitable means of heating to maintain the process plant and equipment in operation are to be provided.

3.13.17 Where flammable fluids are heated, a high temperature alarm and independent controls with manual reset are to be fitted to the heating elements to cut off the heating supply when the temperature of the fluid reaches a predetermined level, except where the maximum temperature of the heating medium remains limited to a value below 200°C.

3.13.18 Heating pipes in contact with flammable fluids are to be of iron, steel, approved aluminium alloy or approved copper alloy. After being fitted on board, the pipes are to be hydraulically tested in accordance with the requirements of Ch 12,8.1.

3.13.19 Where steam is used as the heating medium for heating oil fuel or lubricating oil in bunkers, tanks, heaters or separators, the condensate is to be led to an observation tank located in an easily accessible, well ventilated and well lighted position where it can be readily observed whether or not it is free from oil. Scum pipes from the observation tank are to be led to a waste oil tank.

3.13.20 Where it is proposed to use a heating medium other than steam or water, full particulars of the proposed arrangements are to be submitted for consideration.

3.13.21 Electric heating elements are to be fitted with automatic temperature control, a high temperature alarm and an independent sensor and cut-out with manual reset. Where the elements are self-regulating and are limited to temperatures below 200°C, the independent sensor and cut-out may be omitted. For electric elements heating fluids in bunkers, tanks, heaters or separators, means are to be provided to ensure that they are submerged at all times when the current is flowing, by provision of a low-level sensor to cut off the power supply at a level above that at which the heating element would be exposed.

3.13.22 *See also* Section 13 for alarm requirements for unattended tanks and heaters.

3.13.23 Tanks and heaters in which oil fuel is heated are to be provided with suitable means of ascertaining the temperature of the oil fuel. Such thermometers or temperature sensors are to be fitted in blind pockets.

3.13.24 Arrangements for the storage, distribution and utilisation of oil fuel, oil used in pressure lubrication systems and other flammable fluids employed under pressure are to be such as to minimise the risk of fire and to ensure the safety of persons on board. Pipes, valves and fittings in such systems are to be of approved materials, having regard to the risk and effects of fire. Valves and fittings which incorporate elastomeric sealing materials are to be fire-tested to an acceptable National Standard.

3.13.25 The use of flammable materials such as certain plastics and wood is to be avoided in machinery spaces as far as practicable.

3.13.26 Pipes containing flammable fluids are to be led remote from hot surfaces and electrical equipment, but where this is impracticable, are to have a minimum number of joints, be well protected against mechanical damage and heat radiation, and be installed in well lighted and readily visible positions. Where necessary, pipes should be screened or otherwise suitably protected to avoid leakage or spray impinging onto hot surfaces or into machinery air intakes. Where practicable, leakages from high pressure oil fuel pipes should be collected and arrangements for an alarm provided, *see also* Ch 2,7.

3.13.27 Filters and strainers are to be located to avoid oil spray or oil leakages onto hot surfaces or other sources of ignition, or onto rotating machinery parts. Where necessary, shielding is to be provided and the arrangements are to allow easy access for routine maintenance. The design of filters and strainers is to be such that they cannot be opened when under pressure and suitable means for pressure release are to be provided, with drain pipes led to a safe location.

3.13.28 Tanks containing flammable fluids are not to be situated directly above machinery items, boilers or other hot surfaces where leakage or spillage from the tanks could be ignited, *see also* Ch 1,4.

3.13.29 Where daily service oil fuel tanks are filled automatically or by remote control, means should be provided to prevent overflow spillage through the air pipe. Other equipment such as oil fuel purifiers and heaters which treats flammable fluids automatically should have arrangements to prevent overflow spillage and, wherever practicable, should be installed in a special space reserved for such equipment. *See* Ch 13,12 regarding the termination of air pipes.

3.13.30 Drip trays of ample size and having suitable drainage arrangements are to be provided at pumps and equipment where there is a possibility of leakage. Valves and fittings should be located in well lighted and readily visible positions. Drip trays are not required where pumps and equipment are located in special compartments either inside or outside machinery spaces with approved overall drainage arrangements.

3.13.31 The location and arrangement of short sounding pipes to fuel and lubricating oil tanks is to be in accordance with Ch 13,12.

3.13.32 Separate oil fuel units are to be placed in a spill tray of ample size having drainage arrangements leading to a drain tank of suitable size, *see* Section 4.

3.13.33 *See also* Section 13 for alarm requirements for unattended tanks and miscellaneous machinery.

■ *Section 4* Oil fuel pumps, pipes, fittings, tanks, etc.

4.1 Transfer pumps

4.1.1 Where a power driven pump is necessary for transferring oil fuel, a standby pump is to be provided and connected ready for use, or, alternatively, emergency connections may be made to one of the unit pumps or to another suitable power driven pump.

4.2 Control of pumps

4.2.1 The power supply to all independently driven oil fuel transfer and pressure pumps is to be capable of being stopped from a position outside the space which will always be accessible in the event of fire occurring in the compartment in which they are situated, as well as from the compartment itself.

4.3 Relief valves on pumps

4.3.1 All pumps which are capable of developing a pressure exceeding the design pressure of the system are to be provided with relief valves. Each relief valve is to be in closed circuit, i.e., arranged to discharge back to the suction side of the pump and to limit effectively the pump discharge pressure to the design pressure of the system.

4.4 Pump connections

4.4.1 Valves or cocks are to be interposed between the pumps and the suction and discharge pipes, in order that any pump may be shut off for opening up and overhauling.

4.5 Pipes conveying oil

4.5.1 Pipes conveying oil under pressure are to be of seamless steel or other approved material having flanged or welded joints, and are to be placed in sight above the platform in well lighted and readily accessible parts of the machinery spaces. The number of flanged joints is to be kept to a minimum.

4.5.2 Where pipes convey heated oil under pressure the flanges are to be machined, and the jointing material, which is to be impervious to oil heated to 150°C, is to be the thinnest possible, so that flanges are practically metal to metal. The scantlings of the pipes and their flanges are to be suitable for a pressure of at least 13,7 bar (14 kgf/cm^2) or for the design pressure, whichever is the greater.

4.5.3 The short joining lengths of pipes to the burners from the control valves at the boiler may have cone unions, provided these are of specially robust construction.

4.5.4 Flexible hoses of approved material and design may be used for the burner pipes, provided that spare lengths, complete with couplings, are carried on board.

4.5.5 For requirements relating to flexible hoses, *see* Ch 12,7.

4.6 Low pressure pipes

4.6.1 Transfer, suction and other low pressure oil pipes and all pipes passing through oil storage tanks are to be made of cast iron or steel, having flanged joints suitable for a working pressure of not less than 6,9 bar (7 kgf/cm^2). The flanges are to be machined and the jointing material is to be impervious to oil. Where the pipes are 25 mm bore or less, they may be of seamless copper or copper alloy, except those which pass through oil storage tanks. Oil pipes within the engine and boiler spaces are to be fitted where they can be readily inspected and repaired.

4.6.2 For requirements regarding bilge pipes in way of double bottom tanks and deep tanks, *see* Ch 13,7.9 and 7.10.

4.7 Valves and cocks

4.7.1 Valves, cocks and their pipe connections are to be so arranged that oil cannot be admitted into tanks which are not structurally suitable for the carriage of oil or into tanks which can be used for the carriage of fresh water.

4.7.2 All valves and cocks forming part of the oil fuel installation are to be capable of being controlled from readily accessible positions which, in the engine and boiler spaces, are to be above the working platform, *see also* Ch 13,2.3.

4.7.3 Every oil fuel suction pipe from a double bottom tank is to be fitted with a valve or cock.

4.8 Valves on deep tanks and their control arrangements

4.8.1 Every oil fuel suction pipe from a storage, settling and daily service tank situated above the double bottom, and every oil fuel levelling pipe within the boiler room or engine room, is to be fitted with a valve or cock secured to the tank.

4.8.2 The valves and cocks mentioned in 4.8.1 are to be capable of being closed locally and from positions outside the space in which the tank is located. The remote controls are to be accessible in the event of fire occurring in the deep tank's space. Instructions for closing the valves or cocks are to be indicated at the valves and cocks and at the remote control positions.

4.8.3 The control for remote operation of the valve on the emergency generator fuel tank is to be in a separate location from the controls for the remote operation of other valves for tanks located in machinery spaces.

4.8.4 In the case of tanks of less than 500 litres capacity, consideration will be given to the omission of remote controls.

4.8.5 Every oil fuel suction pipe which is led into the engine and boiler spaces, from a tank situated above the double bottom outside these spaces, is to be fitted in the machinery space with a valve controlled as in 4.8.2, except where the valve on the tank is already capable of being closed from an accessible position above the bulkhead deck.

4.8.6 Where the filling pipes to deep oil tanks are not connected to the tanks near the top, they are to be provided with non-return valves at the tanks or with valves or cocks fitted and controlled as in 4.8.2.

4.9 Water drainage from settling tanks

4.9.1 Settling tanks are to be provided with means for draining water from the bottom of the tanks.

4.9.2 If settling tanks are not provided, the oil fuel bunkers or daily service tanks are to be fitted with water drains.

4.9.3 Open drains for removing the water from oil tanks are to be fitted with valves or cocks of self-closing type, and suitable provision is to be made for collecting the oily discharge.

4.10 Relief valves on oil heaters

4.10.1 Relief valves are to be fitted on the oil side of heaters and are to be adjusted to operate at a pressure of 3,4 bar (3,5 kgf/cm^2) above that of the supply pump relief valve, *see* 4.3. The discharge from the relief valves is to be led to a safe position.

4.11 Filling arrangements

4.11.1 Filling stations are to be isolated from other spaces and are to be efficiently drained and ventilated.

4.11.2 Provision is to be made against over-pressure in the filling pipelines, and any relief valve fitted for this purpose is to discharge to an overflow tank or other safe position.

4.12 Transfer arrangements – Accommodation units

4.12.1 In accommodation units, provision is to be made for the transfer of oil fuel from any oil fuel storage or settling tank to any other oil fuel storage or settling tank in the event of fire or damage.

4.13 Alternative carriage of oil fuel and water ballast

4.13.1 Where it is intended to carry oil fuel and water ballast in the same compartments alternatively, the valves or cocks connecting the suction pipes of these compartments with the ballast pump and those connecting them with the oil fuel transfer pump are to be so arranged that the oil may be pumped from any one compartment by the oil fuel pump at the same time as the ballast pump is being used on any other compartment. In accommodation units the arrangement will require to be specially approved.

4.13.2 Where settling or service tanks are fitted, each having a capacity sufficient to permit 12 hours' normal service without replenishment, the above requirement may be dispensed with.

4.13.3 Attention is drawn to the statutory regulations issued by National Authorities in connection with the *International Convention for the Prevention of Pollution of the Sea by Oil, 1973/78*.

4.14 Deep tanks for the alternative carriage of oil, or water ballast or dry cargo dry storage spaces

4.14.1 In the case of deep tanks which can be used for the carriage of oil or water ballast or dry stores, provision is to be made for blank flanging the oil and water ballast filling and suction pipes, also the steam heating coils if retained in place, when the tank is used for dry stores, and for blank flanging the bilge suction pipes when the tanks are used for oil or water ballast.

4.15 Separation of oil storage from oil fuel

4.15.1 Pipes conveying vegetable oils or similar storage oils are not to be led through oil fuel tanks, nor are oil fuel pipes to be led through tanks containing these storage oils. For requirements regarding provision of cofferdams between oil and water tanks, *see* Pt 3, Ch 3,4.7 of the Rules for Ships.

4.16 Fresh water piping

4.16.1 Pipes in connection with compartments used for storing fresh water are to be separate and distinct from any pipes which may be used for oil or oily water, and are not to be led through tanks which contain oil, nor are oil pipes to be led through fresh water tanks.

4.17 Separate oil fuel tanks

4.17.1 Where separate oil fuel tanks are permitted, their construction is to be in accordance with the requirements of 4.17.2 to 4.17.6, *see also* SOLAS 1974 as amended Reg.II-2/B4.2.2.3.2.

4.17.2 In general, the minimum thickness of the plating of service, settling and other oil tanks, where they do not form part of the structure of the unit, is to be 5 mm, but in the case of very small tanks, the minimum thickness may be 3 mm.

4.17.3 For rectangular steel tanks of welded construction, the plate thicknesses are to be not less than those indicated in Table 14.4.1. The stiffeners are to be of approved dimensions.

Table 14.4.1 Plate thickness of separate oil fuel tanks

Thickness of plate, mm	Head from bottom of tank to top of overflow pipe, metres				
	2,5	3,0	3,7	4,3	4,9
	Breadth of panel, mm				
5	585	525	–	–	–
6	725	645	590	–	–
7	860	770	700	650	–
8	1000	900	820	750	700
10	1280	1140	1040	960	900

4.17.4 The dimension given in Table 14.4.1 for the breadth of the panel is the maximum distance allowable between continuous lines of support, which may be stiffeners, wash-plates or the boundary of the tank.

4.17.5 Where necessary, stiffeners are to be provided, and if the length of the stiffener exceeds twice the breadth of the panel, transverse stiffeners are also to be fitted, or, alternatively, tie bars are to be provided between stiffeners on opposite sides of the tank.

4.17.6 On completion, the tanks are to be tested by a head of water equal to the maximum to which the tanks may be subjected, but not less than 2,5 m above the crown of the tank.

4.18 Oil fuel service tanks

4.18.1 An oil fuel service tank is an oil fuel tank which contains only the required quality of fuel ready for immediate use.

4.18.2 Two oil fuel service tanks, for each type of fuel used on board, necessary for propulsion and generator systems, are to be provided. Each tank is to have a capacity for at least eight hours' operation, at sea, at maximum continuous rating of the propulsion plant and/or generating plant associated with that tank.

4.18.3 The arrangement of oil fuel service tanks is to be such that one tank can continue to supply oil fuel when the other is being cleaned or opened up for repair.

4.18.4 For units of less than 500 gross tonnage, the capacity of each oil fuel service tank required by 4.18.2 may be less than for eight hours' operation, where the class notation includes a service restriction.

4.19 Arrangements for fuels with a flash point between 43° and 60°

4.19.1 Fuel oil tanks other than those in double bottom compartments shall be located outside 'Category A' machinery spaces, *see also* Pt 3, Ch 3,4.7 of the Rules for Ships.

4.19.2 Provisions are to be made for the measurement of oil fuel temperature at the pump suction pipe.

4.19.3 Stop valves are to be provided at the inlet and outlet side of oil fuel strainers.

4.19.4 Pipe joints shall be either welded or spherical type union joints.

■ *Section 5* Steam piping systems

5.1 Provision for expansion

5.1.1 In all steam piping systems, provision is to be made for expansion and contraction to take place without unduly straining the pipes.

5.1.2 Where expansion pieces are used, particulars are to be submitted.

5.1.3 For installation requirements regarding expansion pieces, *see* Ch 13,2.7.

5.2 Drainage

5.2.1 The slope of the pipes and the number and position of the drain valves or cocks are to be such that water can be efficiently drained from any portion of the steam piping system when the unit is in normal trim and is either upright or has a list of up to 5°.

5.2.2 Arrangements are to be made for ready access to the drain valves or cocks.

5.3 Soot cleaning drains

5.3.1 The capacity of the drains from exhaust gas economisers/boilers is to be sufficient to remove all wash water or condensate generated by installed washing systems and arrangements are to be such that engines and turbochargers are protected from wash water or condensate drainage from the washing system.

5.3.2 Adequate arrangements are to be made for the collection and disposal of the waste water generated during periodic water washing of the exhaust gas economiser/boiler. Details are to be submitted for approval.

5.4 Pipes in way of holds

5.4.1 In general, steam pipes are not to be led through spaces which may be used for cargo, but where it is impracticable to avoid this arrangement, plans are to be submitted for consideration. The pipes are to be efficiently secured and insulated, and well protected from mechanical damage. Pipe joints are to be as few as practicable and preferably butt welded.

5.4.2 If these pipes are led through shaft tunnels, pipe tunnels in way of dry storage spaces or through duct keels, they are to be efficiently secured and insulated.

5.5 Reduced pressure lines

5.5.1 Pipelines which are situated on the low pressure side of reducing valves, and which are not designed to withstand the full pressure at the source of supply, are to be fitted with pressure gauges and with relief valves having sufficient discharge capacity to protect the piping against excessive pressure.

5.6 Steam for fire-extinguishing in dry storage spaces

5.6.1 Where steam is used for fire-extinguishing in dry storage spaces provision is to be made to prevent damage to stores by leakage of steam or by drip.

5.6.2 Details of the proposed precautionary measures are to be submitted.

■ *Cross-reference*

For steam heating arrangements for oil fuel, stored oil or lubricating oil, *see* 2.7.

■ *Section 6*
Boiler feed water, condensate and thermal fluid circulation systems

6.1 Feed water piping

6.1.1 Two separate means of feed are to be provided for all main and auxiliary boilers which are required for essential services. In the case of steam/steam generators, one means of feed will be accepted provided steam for essential services is available simultaneously from another source.

6.2 Feed and circulation pumps

6.2.1 Two or more feed pumps are to be provided of sufficient capacity to supply the boilers under full load conditions with any one pump out of action.

6.2.2 Feed pumps may be worked from the main engines or may be independently driven, but at least one of the pumps required in 6.2.1 is to be independently driven.

6.2.3 In twin screw units in which there is only one independent feed pump, each main engine is to be fitted with a feed pump. Where all the feed pumps are independently driven, the pumps are to be connected to deal with the condensate from both engines or from either engine.

6.2.4 Independent feed pumps required for feeding the main boilers are to be fitted with automatic regulators for controlling their output.

6.2.5 The arrangement of forced water/thermal fluid circulation pumps for exhaust gas economisers/ boilers/thermal heaters is to be such that where required, the flow through the exhaust gas economiser/boiler/thermal heater is to be established prior to engine start-up. Where applicable, provision is to be made to allow for operation in the dry condition.

6.2.6 The forced circulation flow required by 6.2.5 is to be maintained on completion of engine shut-down for a sufficient duration in accordance with the exhaust gas economiser/boiler/thermal heater manufacturer’s instructions. Details of arrangements are to be submitted for approval.

6.2.7 Where arrangements are such that exhaust gas economisers/boilers/thermal heaters require forced water /thermal fluid circulation, standby pumps are to be fitted, *see* Pt 6, Ch 1,3.1.3.

6.3 Harbour feed pumps

6.3.1 Where main engine-driven feed pumps are fitted and there is only one independent feed pump, a harbour feed pump or an injector is to be fitted to provide the second means of feed to the boilers which are in use when the main engines are not working.

6.3.2 The harbour feed pump required by 6.3.1 may be used for general service, provided that it is not connected to tanks containing oil, or to tanks, cofferdams and bilges which may contain oily water.

6.3.3 The valves on the suction pipes from the hotwell or condenser and the feed drain tank or filter are to be of the non-return type.

6.4 Condensate pumps

6.4.1 Two or more extraction pumps are to be provided for dealing with the condensate from the main and auxiliary condensers, at least one of which is to be independently driven. Where one of the independent feed pumps is fitted with direct suctions from the condensers and a discharge to the feed tank, it may be accepted for this purpose.

6.5 Valves and cocks

6.5.1 Feed and condensate pumps are to be provided with valves or cocks, interposed between the pumps and the suction and the discharge pipes, so that any pump may be opened up for overhaul while the others continue in operation.

6.6 Reserve feed water

6.6.1 All units fitted with boilers are to be provided with storage space for reserve feed water, the structural and piping arrangements being such that this water cannot be contaminated by oil or oily water, *see* Pt 3, Ch 3,4.7 of the Rules for Ships for structural arrangements.

6.6.2 For main boilers, one or more evaporators, of adequate capacity, are also to be provided.

■ *Cross-reference*

For feed water level regulators for water tube boilers, *see* Ch 10,16.8.

■ *Section 7* Engine cooling water systems

7.1 Main supply

7.1.1 Provision is to be made for an adequate supply of cooling water to the main propelling machinery and essential auxiliary engines, also to the lubricating oil and fresh water coolers and air coolers for electric propelling machinery, where these coolers are fitted. The cooling water pump(s) may be worked from the engines or be driven independently.

7.1.2 In the case of main steam turbine installations, a sea inlet scoop arrangement may replace the main sea-water circulating pump, subject to the conditions stated in 7.2.2(c).

7.2 Standby supply

7.2.1 Provision is also to be made for a separate supply of cooling water from a suitable independent pump of adequate capacity.

7.2.2 The following arrangements are acceptable depending on the purpose for which the cooling water is intended:

(a) Where only one main engine is fitted, the standby pump is to be connected ready for immediate use.
(b) Where more than one main engine is fitted, each with its own pump, a complete spare pump of each type may be accepted.
(c) Where a sea inlet scoop arrangement is fitted, and there is only one independent condenser circulating pump, a further pump, or a connection to the largest available pump suitable for circulation duties, is to be fitted to provide the second means of circulation when the ship unit is manoeuvring. The pump is to be connected ready for immediate use.
(d) Where fresh water cooling is employed for main and/or auxiliary engines, a standby fresh water pump need not be fitted if there are suitable emergency connections from a salt water system.
(e) Where each auxiliary is fitted with a cooling water pump, standby means of cooling need not be provided. Where, however, a group of auxiliaries is supplied with cooling water from a common system, a standby cooling water pump is to be provided for this system. This pump is to be connected ready for immediate use and may be a suitable general service pump.

7.3 Selection of standby pumps

7.3.1 When selecting a pump for standby purposes, consideration is to be given to the maximum pressure which it can develop if the overboard discharge valve is partly or fully closed and, when necessary, condenser doors, water boxes, etc., are to be protected by an approved device against inadvertent over-pressure. *See* Ch 3,6.3 for the hydraulic test pressure which condensers are required to withstand.

7.4 Relief valves on main cooling water pumps

7.4.1 Where cooling water pumps can develop a pressure head greater than the design pressure of the system, they are to be provided with relief valves on the pump discharge to limit effectively the pump discharge pressure to the design pressure of the system. For location of relief valves, *see* Ch 13,7.8.

7.5 Sea inlets

7.5.1 No fewer than two sea inlets are to be provided for the pumps supplying the sea-water cooling system, one for the main pump and one for the standby pump. Alternatively, the sea inlets may be connected to a suction line available to main and standby pumps.

7.5.2 Where standby pumps are not connected ready for immediate use, *see* 7.2.2(b), the main pump is to be connected to both sea inlets.

7.5.3 Cooling water pump sea inlets are to be low inlets and one of them may be the ballast pump or general service pump sea inlet.

7.5.4 The auxiliary cooling water sea inlets are preferably to be located one on each side of the unit.

7.6 Strainers

7.6.1 Where sea-water is used for the direct cooling of the main engines and essential auxiliary engines, the cooling water suction pipes are to be provided with strainers which can be cleaned without interruption to the cooling water supply.

■ *Cross-reference*

For guidance on metal pipes for water services, *see* Ch 12,11.

■ *Section 8*
Lubricating oil systems

8.1 General requirements

8.1.1 In addition to the requirements detailed in this Section, the requirements of Sections 2 and 4 are to be complied with in so far as they are applicable. In all cases 2.9.1 to 2.9.3, 4.2, 4.3, 4.5, 4.8, 4.11 and 4.17 are to apply.

8.2 Pumps

8.2.1 Where lubricating oil for the main engine(s) is circulated under pressure, a standby lubricating oil pump is to be provided where the following conditions apply:

(a) The lubricating oil pump is independently driven and the total output of the main engine(s) exceeds 370 kW (500 shp).
(b) One main engine with its own pump is fitted and the output of the engine exceeds 370 kW (500 shp).
(c) More than one main engine each with its own lubricating oil pump is fitted and the output of each engine exceeds 370 kW (500 shp).

8.2.2 The standby pump is to be of sufficient capacity to maintain the supply of oil for normal conditions with any one pump out of action. The pump is to be fitted and connected ready for immediate use, except that where the conditions referred to in 8.2.1(c) apply a complete spare pump may be accepted. In all cases satisfactory lubrication of the engines is to be ensured while starting and manoeuvring.

8.2.3 Similar provisions to those of 8.2.1 and 8.2.2 are to be made where separate lubricating oil systems are employed for piston cooling, reduction gears, oil operated couplings and controllable pitch propellers, unless approved alternative arrangements are provided.

8.2.4 Independently driven pumps of rotary type are to be fitted with a non-return valve on the discharge side of the pump.

8.3 Alarms

8.3.1 All main and auxiliary engines and turbines intended for essential services are to be provided with means of indicating the lubricating oil pressure supply to them. Where such engines and turbines are of more than 37 kW (50 shp), audible and visual alarms are to be fitted to give warning of an appreciable reduction in pressure of the lubricating oil supply. Further, these alarms are to be actuated from the outlet side of any restrictions, such as filters, coolers, etc.

8.4 Emergency supply for propulsion turbines and propulsion turbo-generators

8.4.1 A suitable emergency supply of lubricating oil is to be arranged to come automatically into use in the event of a failure of the supply from the pump.

8.4.2 The emergency supply may be obtained from a gravity tank containing sufficient oil to maintain adequate lubrication for not less than six minutes, and, in the case of propulsion turbo-generators, until the unloaded turbine comes to rest from its maximum rated running speed.

8.4.3 Alternatively, the supply may be provided by the standby pump or by an emergency pump. These pumps are to be so arranged that their availability is not affected by a failure in the power supply.

8.4.4 For automatic shut-down arrangements of main turbines in the event of failure of the lubrication system, *see* Ch 3,5.1 and Pt 6, Ch 1,4.4 of the Rules for Ships.

8.5 Maintenance of bearing lubrication

8.5.1 The arrangements for lubricating bearings and for draining crankcase and other oil sumps of main and auxiliary engines, gearcases, electric generators, motors, and other running machinery are to be so designed that lubrication will remain efficient with the ship unit inclined under the conditions as shown in Ch 1,3.7.

8.5.2 For details of the requirements relating to the lubrication of bearings of electric generators and motors, *see* Pt 6, Ch 2,1.10 and Section 8.

8.6 Filters

8.6.1 Where the lubricating oil for main propelling engines is circulated under pressure, provision is to be made for the efficient filtration of the oil. The filters are to be capable of being cleaned without stopping the engine or reducing the supply of filtered oil to the engine. Proposals for an automatic by-pass for emergency purposes in high speed engines are to be submitted for special consideration.

8.6.2 In the case of propulsion turbines and their gears, arrangements are to be made for the lubricating oil to pass through magnetic strainers and fine filters. Generally, the openings in the filter elements are to be not coarser than required by the manufacturer of the turbines, especially for the supply to turbine thrust bearings.

8.7 Cleanliness of pipes and fittings

8.7.1 Extreme care is to be taken to ensure that lubricating oil pipes and fittings, before installation, are free from scale, sand, metal particles and other foreign matter.

8.8 Lubricating oil drain tank

8.8.1 Where an engine lubricating oil drain tank extends to the bottom shell plating in units that are required to be provided with a double bottom, a shut-off valve is to be fitted in the drainpipe between the engine casing and the double bottom tank. This valve is to be capable of being closed from an accessible position above the level of the lower platform.

8.9 Lubricating oil contamination

8.9.1 The materials used in the storage and distribution of lubricating oil are to be selected such that they do not introduce contaminants or modify the properties of the oil. The use of cadmium or zinc in lubricating oil systems where they may normally come into contact with the oil is not permitted.

8.9.2 Arrangements are to be made for each forced lubrication system, renovation system, ready to use tank(s) and their associated rundown lines to drain tanks to be flushed after system installation and prior to running of machinery. The flushing arrangements are to be in accordance with the equipment manufacturer's procedures and recommendations.

8.9.3 For prevention of ingress of water into lubricating oil tanks via air pipes, *see* Ch 13,12.5.4.

8.9.4 The design and construction of engine and gear box piping arrangements are to prevent contamination of engine lubricating oil systems by leakage of cooling water or from bilge water where engines or gearboxes are partly installed below the lower platform. Where flexibility is required to accommodate movement between the engine and sump tank, any flexible joint assembly is to be of an approved type suitable for its intended application.

8.9.5 Where there is a permanently attached oil filling pipe and cap provided for an engine or other item of machinery, provision is to be made for the topping up oil to safely pass through a suitable strainer to prevent unwanted matter getting into the lubricating oil system. The caps are to be capable of being secured in the closed position.

8.9.6 Sampling points are to be provided that enable samples of lubricating oil to be taken in a safe manner. The sampling arrangements are to have the capability to provide samples when machinery is running and are to be provided with valves and cocks of the self-closing type and located in positions as far removed as possible from any heated surface or electrical equipment.

8.10 Deep tank valves and their control arrangements

8.10.1 The requirements for remote operation of valves on deep tank suction pipes may be waived where the valves are closed during normal operation.

8.10.2 Remotely operated valves on lubricating oil deep tank suctions should not be of the quick-closing type where inadvertent use would endanger the safe operation of the main propulsion and essential auxiliary machinery.

■ *Cross-references*

For air, sounding pipes and gauge glasses, *see* Ch 13,12. For separation of lubricating oil tanks from fuel tanks, *see* Pt 3, Ch 3,4.7 of the Rules for Ships.

■ *Section 9* Hydraulic systems

9.1 General

9.1.1 The requirements of this Section are applicable to flammable oils employed under pressure in power transmission, control, actuating and heating systems, and hydraulic media in systems which are providing essential services.

9.1.2 The arrangements for storage, distribution and utilisation of hydraulic and flammable oils employed in the systems defined in 9.1.1 are to comply with the provisions of 2.9.1 to 2.9.3, 4.3, 4.5, 4.11 and 4.17 where applicable.

9.2 System arrangements

9.2.1 Hydraulic fluids are to be suitable for the intended purpose under all operating service conditions.

9.2.2 Materials used for all parts of hydraulic seals are to be compatible with the working fluid at the appropriate working temperature and pressure.

9.2.3 Provision is to be made for hand operation of the systems in an emergency, unless an acceptable alternative is available.

9.2.4 Where hydraulic securing arrangements are applied, the system is to be capable of being locked in the closed position so that in the event of hydraulic system failure the securing arrangements will remain locked.

9.2.5 Where pilot operated non-return valves are fitted to hydraulic cylinders for locking purposes, the valves are to be connected directly to the actuating cylinder(s) without intermediate pipes or hoses.

9.2.6 Hydraulic circuits for securing and locking of bow, inner, stern or shell doors are to be arranged such that they are isolated from other hydraulic circuits when securing and locking devices are in the closed position. For requirements relating to hydraulic steering gear arrangements *see* Ch 19,3.

9.2.7 Suitable oil collecting arrangements for leaks shall be fitted below hydraulic valves and cylinders.

■ *Section 10*
Low pressure compressed air systems

10.1 General

10.1.1 The requirements of this Section are applicable to low pressure (LP) compressed air systems which are essential for pneumatic control and instrumentation purposes. The documentation required by Ch 13,1.3.1 is to provide information to demonstrate compliance with 10.1.2 to 10.1.5.

10.1.2 Low pressure compressed air systems are to produce and distribute cooled compressed air throughout the unit to supply all pneumatic control and instrumentation systems where the air pressure requirements are typically 3 to 10 bar. LP compressed air systems may include air compressors, oil/water separators, filters, dryers, distribution lines and air receivers.

10.1.3 The design of LP compressed air systems is to be capable of providing a continuous flow of air to meet the demands of all essential services under all ambient conditions. This demand may include the use of intermittently used equipment that is part of the unit's equipment, such as power tools for machinery maintenance, testing equipment and line cleaning. Compressed air systems used for diesel engine or gas turbine starting are to comply with the requirements of Ch 2,8 and Ch 4,6 as applicable.

10.1.4 User equipment requirements for the quality of compressed air in terms of dewpoint (dryness), oil content and solid particle count are to be recognised in the selection and configuration of compressors, equipment, filters and dryers which are included in the system.

10.1.5 Configuration arrangements of LP compressed air systems may consist of:

(a) Dedicated LP air compressors and LP air receivers with a distribution system for LP users; or
(b) Supply from the starting air system to dedicated air pressure reducing valves/cross-over stations feeding into a distribution system for LP users.

10.2 Compressors and reducing valves/stations

10.2.1 Where LP air is not derived from the starting air system, at least two LP air compressors are to be provided. The output of any one compressor is to match the total demand of all essential users. The system is to be arranged for auto-start of the compressors and means are to be provided to indicate if any compressor is operating longer and more frequently than the manufacturer's recommended operating periods.

10.2.2 If only one LP air compressor is to be provided, a cross connection to the starting air system is to be made via a reducing valve/cross-connection station.

10.2.3 Where LP air is derived only from the starting air system, at least two means of supplying air to the LP air system are to be provided. Each of the two means of supplying air is to have sufficient capability of supplying the total demand on the LP air system with one of the means out of action.

10.2.4 Where the starting air system is fitted with an auxiliary compressor it is to be capable of continuous running and to be capable of maintaining the stored capacity of starting compressed air in the air receivers as required by Ch 2,8 and Ch 4,6 whilst also supplying essential LP services.

10.2.5 Where the starting air system is designed to maintain sufficient compressed air for LP services and engine starting arrangements, an additional auxiliary compressor will not be required.

10.3 Air receivers

10.3.1 The LP air system and any associated air receivers are to be configured to provide sufficient stored energy to supply LP compressed air without the pressure in the system falling below a level that is insufficient for the operation of all essential users. *See also* Pt 6, Ch 1,2.5.8.

10.3.2 All air receivers are to comply with the requirements of Chapter 11 as applicable.

10.3.3 Stop valves on air receivers are to permit slow opening to avoid sudden pressure rises in the piping system.

10.4 Distribution system

10.4.1 Drain pots with drain valves are to be provided throughout the distribution system at all low points.

10.4.2 Pipelines that are situated on the low pressure side of reducing valves/stations and that are not designed to withstand the full pressure of the source supply are to be provided with pressure gauges and with relief valves having sufficient capacity to protect the piping against excessive pressure.

10.4.3 In-line filters capable of being cleaned/changed without interrupting the flow of filtered air are to be fitted in the system.

10.5 Pneumatic remote control valves

10.5.1 Where valves, which are required by the Rules to be capable of being closed from outside a machinery space, have pneumatic closing arrangements, a dedicated air receiver is to be fitted to supply compressed air to the valves. This air receiver is to be located outside the machinery space.

10.5.2 The air receiver is to be maintained fully charged from the main LP air system via a non-return valve located at the air receiver inlet which is to be locked in the open position.

10.5.3 In the case of accommodation units, a permanently attached hand-operated air compressor capable of charging the air receiver is to be provided in the space in which the air receiver is located.

10.5.4 The capacity of the air receiver is to be sufficient to operate all valves and any other essential supplies such as ventilation flaps without replenishment.

10.6 Control arrangements

10.6.1 The control, alarm and monitoring systems are to comply with Pt 6, Ch 1.

■ *Section 11* Multi-engined units

11.1 General

11.1.1 This Section is applicable to units of less than 500 gross tons and which are not required to comply with the International Convention for the Safety of Life at Sea, 1974, as amended (SOLAS 74), and that have multi-engine installations for propulsion purposes.

11.1.2 For units in which the propulsion systems are independent and the propulsion system prime movers are also fully independent of each other such that in the event of the failure of one of the sources of propulsion power the units will retain the capability of safely manoeuvring under all conditions of service, the following may not be required:

(a) Spare fuel oil booster pump stipulated in 3.10.2.

(b) Spare lubricating oil pump stipulated in 8.2.1(c), 8.2.2 and 8.2.3.

(c) Spare cooling water pump stipulated in 7.2.2(b).

■ *Section 12* Helicopter refuelling facilities

12.1 Fuel storage

12.1.1 Storage tanks and skids are to be located in a designated area as remote as practicable from machinery and accommodation spaces, escape routes and embarkation stations and are to be suitably isolated from areas where there are sources of ignition.

12.1.2 The storage and handling area is to be permanently marked. Instructions for filling fuel are to be posted in the vicinity of the filling area.

12.1.3 The tanks are to be protected from helicopter crashes, mechanical damage, solar and flare radiation and high temperatures as a result of a fire occurring in an adjacent area.

12.1.4 Tanks are to be of approved metallic construction and special attention is to be given to the inspection procedures, mounting and securing arrangements and electrical bonding of the tank and fuel transfer system. Transportable tanks shall be specially designed for their intended use and equipped with suitable fittings, lifting and fixing arrangements and earthing, and are to comply with the relevant Codes for the transportation of dangerous goods in ships.

12.1.5 Tank ventilation pipes are to be fitted with an approved type of vent head with pressure-vacuum valve and flame arrester. The vent outlet is to be located in a safe position away from accommodation spaces and ventilation intakes.

12.1.6 The fuel storage area is to be provided with a collecting tray of suitable capacity for containing leakage from the tanks and pumping units, and for draining any such leakage to a tank or container located in a safe area. For tanks forming an integral part of the unit's structure, cofferdams are to be provided as necessary to contain leakage and prevent contamination of the fuel.

12.2 Fuel pumping and filling

12.2.1 The tank outlet valve is to be mounted directly onto the tank and shall be capable of being closed from a remote location in the event of fire. Ball valves are to be stainless steel, anti-static, fire-tested type.

12.2.2 The pumping unit is to be connected to only one tank at a time. Pipes between the tanks and the pumping unit are to be of stainless steel or equivalent material, or flexible hoses of an approved type, fire-tested to an acceptable National Standard. Such pipes or hoses are to be protected from mechanical damage and be as short as possible. Where a flexible hose is used to connect the pumping unit to a tank, the hose connection is to be of the quick-disconnect, self-closing type.

12.2.3 Pumping units are to be capable of being controlled from the refuelling station.

12.2.4 Pumping units are to incorporate a device to prevent over-pressurisation of the filling hose.

12.2.5 Arrangements for fuel metering and sampling are to be provided.

■ *Section 13*
Control and supervision

13.1 Unattended tanks and miscellaneous machinery

13.1.1 When the tanks and miscellaneous machinery items listed in Table 14.13.1 are operated such that under normal conditions they do not require any manual intervention by the operators, they are to be provided with appropriate alarms and safety arrangements as listed. Alternative arrangements which provide equivalent safeguards will be considered.

13.1.2 The design of the alarm, control and safety systems is to comply with the requirements of Pt 6, Ch 1, 2.

Table 14.13.1 Alarms for unattended tanks and miscellaneous machinery

Item	Alarm	Note
Coolant tanks level	Low	–
Daily service oil fuel tanks level	High and low	One high level alarm may be fitted in a common overflow tank
Daily service oil fuel tanks temperature	High	Where heating arrangements are fitted
Oil fuel settling tanks temperature	High	Where heating arrangements are fitted
Sludge tanks level	High	–
Feed water tanks level	Low	Service tank only
Purifier water seal broken	Fault	–
Purifier oil inlet temperature	High	–
Hydraulic control system pressure	Low	–
Pneumatic control system pressure	Low	–
Oil heater temperature	High	*See also* 2.1.19
Controlled environmental conditions	Abnormal	*See also* Pt 6, Ch 1,1.4

13.2 Unattended incinerators

13.2.1 When incinerators are fitted with automatic or remote controls so that under normal operating conditions they do not require any manual intervention by the operators, they are to be provided with the alarms and safety arrangements required by Table 14.13.2 as listed. Alternative arrangements which provide equivalent safeguards will be considered.

Table 14.13.2 Alarms for unattended incinerators

Item	Alarm	Note
Oil fuel temperature of viscosity	High and low	Heavy oil and sludge
Oil fuel pressure	Low	–
Combustion air pressure	Low	Oil fuel and/or sludge to burners to be shut off automatically
Burner flame and ignition	Failure	Oil fuel and/or sludge to burners to be shut off automatically. *See* Note
Furnace temperature	High	Oil fuel and/or sludge to burners to be shut off automatically
Furnace temperature	Low	If applicable
Exhaust temperature	High	–

NOTE
Combustion spaces are to be purged automatically before re-ignition takes place in the event of a flame out on all burners.

13.2.2 The design of the alarm, control and safety systems is to comply with the requirements of Pt 6, Ch 1,2.

13.2.3 Where machinery is arranged to start automatically or from a remote control station, interlocks are to be provided to prevent start-up under conditions which could cause hazard.

13.2.4 Where arrangements are provided to introduce solid waste into the furnace these are to be such that there is no risk of a fire hazard.

13.2.5 The combustion temperature is to be controlled to ensure that all liquid and solid waste is efficiently burned without exceeding predetermined temperature limits.

■ *Section 14* Requirements for boilers and heaters

14.1 Scope

14.1.1 In the context, the term boilers also includes steam boilers, Glycol/Amine/Selexol, etc., reboilers and thermal oil heaters, which are fired units.

14.2 General

14.2.1 For all fired boilers, the pre-purge is to be sufficient to give at least 5 air changes in the furnace and/or at least 2,5 complete air changes of the furnace and uptakes, whichever is greater.

14.2.2 Combustion air is to be taken from a safe area.

14.2.3 Gas detectors are to be fitted in the combustion air intake trunking, that will shut down the boiler and alarm at a manned station.

14.2.4 Gas-fired boilers are to be fitted with fuel oil pilot igniter system. A fuel gas system or electric spark ignition for the main burner are not acceptable systems.

14.2.5 Boilers are to be located in areas designated 'safe areas'. If the boiler cannot be fitted in an area designated 'safe area' then it must be fitted with the following:

(a) The furnace must be a closed front type.
(b) The combustion air must be ducted from an area designated a 'safe area' and fitted with a flame arrestor.
(c) The combustion air intake is to be fitted with a gas detector which will alarm and shut down the flame on gas detection.
(d) A gas detector is to be fitted near to the boiler in the compartment in which the boiler is located.
(e) The maximum surface temperatures as given in the Rules are to be complied with.

14.2.6 Fig. 14.14.1 shows a typical arrangement for a boiler room.

14.2.7 For boilers that use fuel gas *see* Pt 5, Ch 16 as applicable.

14.2.8 For boilers located in a safe area, combustion air may be taken from the boiler compartment.

14.2.9 Boiler compartment ventilation is to be a minimum of 12 air changes per hour.

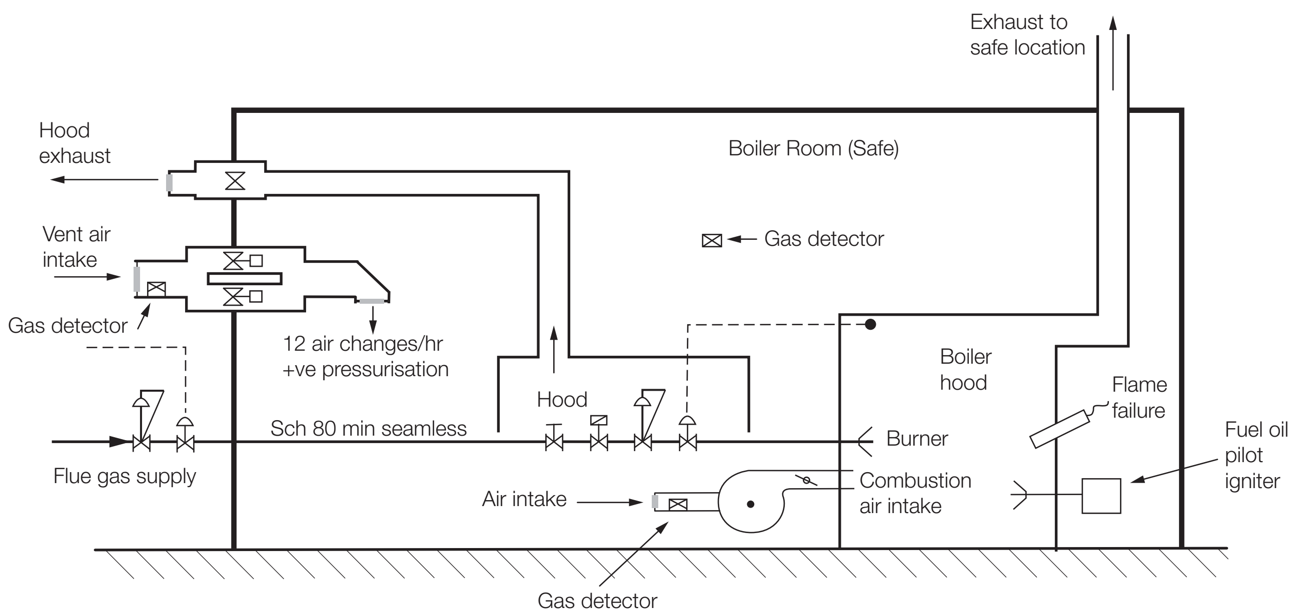


Fig. 14.14.1 Diagram showing the typical arrangements for a boiler room

14.2.10 All boilers are to be fitted with a method of leak detection depending upon the fluid contained in the boiler. Adequate leak collection and drainage is to be provided.

14.3 Thermal oil boilers/heaters

14.3.1 The requirements for thermal oil boilers and heaters are given in Pt 5, Ch 15,6.5.

■ *Section 1* General requirements

1.1 Application

1.1.1 The requirements of this Chapter are additional to those of Chapter 13 and are applicable to units which are intended for the storage of oil in bulk.

1.1.2 Additional requirements with respect to unit types as indicated in this Section are also to be complied with as applicable.

1.1.3 These systems are generally to be separate from the piping systems associated with the drilling/process plant systems, but consideration will be given to cross-connections for drilling/process operations, where this can be shown to be necessary.

1.1.4 The requirements are primarily intended for units which are to store flammable liquids having a flash point not exceeding 60°C (closed-cup test).

1.1.5 Where units are intended to store specific cargoes which are non-flammable or which have a flash point exceeding 60°C, the requirements will be modified, where necessary, to take account of the lesser hazards associated with the cargoes.

1.1.6 For the definition of, and use of, diesel engine power units and equipment in hazardous areas, *see* Pt 7, Ch 2,7.

1.2 Plans and particulars

1.2.1 In addition to the plans and particulars required in Chapter 13, the following plans (in a diagrammatic form) are to be submitted for consideration:

- Pumping arrangement at the fore and aft ends and drainage of cofferdams and pump-rooms.
- General arrangement of cargo piping in tanks and on deck.
- General arrangement of oil storage tank vents. The plan is to indicate the type and position of the vent outlets from any superstructure, erection, air intake, etc.
- Arrangement of inert gas piping system together with details of inert gas generating plant including all control and monitoring devices.
- Piping arrangements for cargo oil (F.P. 60°C or above, closed cup test).
- Ventilation arrangements of cargo and/or ballast pump-rooms and other enclosed spaces which contain cargo handling equipment.
- Arrangements for venting, purging and gas measurement for double hull and double bottom spaces.
- Details of alarms and safety arrangements required by 1.6, *see also* Pt 6, Ch 1,2.

1.3 Materials

1.3.1 All materials used in the oil storage pumping and piping systems are to be suitable for use with the intended oils and, where applicable, they are to comply with the requirements of Chapter 12.

1.3.2 The requirements of 1.3.1 are also applicable to other piping systems which may come into contact with stored oil.

1.4 Design

1.4.1 All piping, valves and fittings are to be suitable for the maximum pressure to which the system can be subjected.

1.4.2 Piping subject to pressure is to be of seamless or other approved type, and is to comply with the requirements of Chapter 12.

1.5 Hazardous zones and spaces

1.5.1 Oil engines, or any other equipment which could constitute a possible source of ignition, are not to be situated within oil storage tanks, pump-rooms, cofferdams or other spaces liable to contain explosive vapours, or in spaces or zones immediately adjacent to oil storage or slop tanks. The temperature of steam, or other fluid, in pipes (or heating coils) in these spaces is not to exceed 220°C.

1.5.2 For definition of hazardous zones and spaces and requirements for electrical equipment within such spaces, *see* Pt 6, Ch 2,14.5 of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships).

1.5.3 For the requirements for earthing and bonding of pipework for the control of static electricity, *see* Pt 6, Ch 2,1.13.

1.6 Oil storage pump-room

1.6.1 Oil storage pump-rooms are to be totally enclosed and are to have no direct communication with machinery spaces. For bilge drainage arrangements in pump-room, *see* 2.2.

1.6.2 Pump-rooms are to be situated within, or adjacent to the oil storage tank area and are to be provided with ready means of access from the open deck, *see also* Pt 4, Ch 9,13 of the Rules for Ships.

1.6.3 In cargo pump-rooms any drain pipes from steam or exhaust pipes from the steam cylinders of the pumps are to terminate well above the level of the bilges.

1.6.4 Alarms and safety arrangements are to be provided as indicated in 1.6.5 and Table 15.1.1. These requirements are applicable to pump-rooms where pumps for stored oil, such as oil storage pumps, stripping pumps, pumps for slop tanks, pumps for COW or similar pumps are provided and not for pump-rooms intended solely for ballast transfer. *See also* 1.6.6.

Table 15.1.1 Alarms and safety arrangements

Item	Alarm	Note
Temperature sensing of bulkhead shaft glands, bearings and pump casings	High *see* Note 1	Cargo, ballast and stripping pumps
Bilge level	High	—
Hydrocarbon concentration	High *see* Note 2	> 10% LEL

NOTES
1. The alarm signals shall trigger continuous visual and audible alarms in the cargo control room or the pump control station.
2. This alarm signal shall trigger a continuous audible and visual alarm in the pump-room, cargo control room, engine control room and bridge.

1.6.5 A system for continuously monitoring the concentrations of hydrocarbon gases within the oil storage pump-room is to be fitted. Monitoring points are to be located in positions where potentially dangerous concentrations may be readily detected. Gas analysing units with non-safe-type measuring equipment may be located outside oil storage areas (e.g., in oil storage control room, navigation bridge or engine room when mounted on the forward bulkhead) provided that:

(a) sampling lines do not pass through gas safe spaces, except where permitted by (e);

(b) the gas sampling pipes are fitted with flame arresters. Sample gas is to be led to the atmosphere with outlets arranged in a safe location, in the open atmosphere;

(c) bulkhead penetrations of sample pipes between safe and hazardous zones are of an approved type. A manual isolating valve is to be fitted in each of the sampling lines at the bulkhead in the safe area;

(d) the gas detection equipment including sampling piping, sampling pumps, solenoid valves and analysing units, are located in a fully enclosed steel cabinet, with a gasketed door, monitored by its own sampling point. At gas concentrations above 30 per cent LEL inside the steel cabinet, the entire gas-analysing unit is to be automatically shut down; and

(e) where the cabinet cannot be arranged on the bulkhead, sample pipes are to be of steel or other equivalent material and without detachable connections, except for the connection points for isolating valves at the bulkhead and analysing units. The sample pipes are to be led by their shortest route.

Sequential sampling is acceptable as long as it is dedicated for the pump-room only, including exhaust ducts, and the detection equipment is capable of monitoring from each sampling head location at intervals not exceeding 30 minutes.

1.6.6 Where items of equipment other than described in Table 15.1.1 are located in the pump-room and are driven by shafts passing through bulkheads, the potential risk of ignition of hydrocarbon gas is to be assessed and proposals for mitigation submitted to LR for consideration.

1.7 Oil storage pump-room ventilation

1.7.1 Oil storage pump-rooms and other closed spaces which contain oil storage handling equipment, and to which regular access is required during oil storage handling operations, are to be provided with permanent ventilation systems of the mechanical extraction type.

1.7.2 The ventilation system is to be capable of being operated from outside the compartment being ventilated and a notice is to be fixed near the entrance stating that no person is to enter the space until the ventilation system has been in operation for at least 15 minutes.

1.7.3 The ventilation systems are to be capable of 20 air changes per hour, based on the gross volume of the pump-room or space.

1.7.4 The ventilation ducting is to be arranged to permit extraction from the vicinity of the pump-room bilges, immediately above the transverse floor plates or bottom longitudinals. An emergency intake is also to be arranged in the ducting at a height of 2 m above the pump-room lower platform and is to be provided with a damper capable of being opened or closed from the weather deck and lower platform level. An arrangement involving a specific ratio of areas of upper emergency and lower main ventilation openings, which can be shown to result in at least the required number of air changes through the lower inlets, can be accepted without the use of dampers. When the lower inlets are sealed off, owing to flooding of the bilges, then at least 75 per cent of the required number of air changes is to be obtainable through the upper inlets. Means are to be provided to ensure the free flow of gases through the lower platform to the duct intakes.

1.7.5 Protection screens of not more than 13 mm square mesh are to be fitted in outside openings of ventilation ducts, and ventilation intakes are to be so arranged as to minimise the possibility of re-cycling hazardous vapours from any ventilation discharge opening. Vent exits are to be arranged to discharge to a safe place on the open deck and comply with the requirements of 1.7.6.

1.7.6 The vent exits from pump-rooms are to discharge at least 3 m above deck, and from the nearest air intakes or openings to accommodation and enclosed working spaces, and from possible sources of ignition.

1.7.7 The ventilation is to be interlocked to the lighting system (except emergency lighting) such that the oil storage pump-room lighting may only come on when the ventilation is in operation. Failure of the ventilation system shall not cause the lighting to go out.

1.8 Non-sparking fans for hazardous areas

1.8.1 The air gap between impeller and housing of the fan is to be not less than 0,1 of the impeller shaft bearing diameter or 2 mm, whichever is the larger, subject also to compliance with 1.8.2(e). Generally, however, the air gap need be no more than 13 mm.

1.8.2 The following combinations of materials are permissible for the impeller and the housing in way of the impeller:

(a) impellers and/or housings of non-metallic material, due regard being paid to the elimination of static electricity,
(b) impellers and housings of non-ferrous metals,
(c) impellers and housings of austenitic stainless steel,
(d) impellers of aluminium alloys or magnesium alloys and a ferrous housing provided that a ring of suitable thickness of non-ferrous material is fitted in way of the impeller,
(e) any combination of ferrous impellers and housings with not less than 13 mm tip clearance,
(f) any combination of materials for the impeller and housing which are demonstrated as being spark proof by appropriate rubbing tests.

1.8.3 The following combinations of materials for impellers and housing are not considered spark proof and are not permitted:

(a) impellers of an aluminium alloy or magnesium alloy and a ferrous housing, irrespective of tip clearance,
(b) impellers of a ferrous material and housings made of an aluminium alloy, irrespective of tip clearance,
(c) any combination of ferrous impeller and housing with less than 13 mm tip clearance, other than permitted by 1.8.2(c).

1.8.4 Electrostatic charges both in the rotating body and the casing are to be prevented by the use of antistatic materials (i.e., materials having an electrical resistance between 5 x 10^4 ohms and 10^8 ohms), or special means are to be provided to avoid dangerous electrical charges on the surface of the material.

1.8.5 Type tests on the complete fan are to be carried out to the Surveyor's satisfaction.

1.8.6 Protection screens of not more than 13 mm square mesh are to be fitted in the inlet and outlet of ventilation ducts to prevent the entry of objects into the fan housing.

1.8.7 The installation of the ventilation units on board is to be such as to ensure the safe bonding to the hull of the units themselves.

1.9 Steam connections to oil storage tanks

1.9.1 Where steaming out and/or fire-extinguishing connections are provided for oil storage tanks or oil storage pipe lines, they are to be fitted with valves of the screw-down non-return type. The main supply to these connections is to be fitted with a master valve placed in a readily accessible position clear of the oil storage tanks.

■ *Cross-reference*

See Pt 6, Ch 1,3 for alarm system requirements.

■ *Section 2*
Piping systems for bilge, ballast, oil fuel, etc.

2.1 Pumping arrangements at ends of unit outside hazardous zones and spaces

2.1.1 The pumping arrangements in the machinery space and at the forward end of the unit are to comply with Chapters 13 and 14, in so far as they are applicable, and with the special requirements detailed in this Section.

2.1.2 Cofferdams, including deep cofferdams on ship or barge-type units, which are required to separate safe areas from hazardous areas, are to be provided with suitable drainage arrangements. Examples of acceptable arrangements are detailed in 2.1.3, 2.1.4 and 2.1.5.

2.1.3 Where installed in a oil storage pump-room, a bilge pump may be used for draining the cofferdam. In ship or barge-type units, a ballast pump in the oil storage pump-room may be used for emptying the after cofferdam, and, where fitted, a ballast pump in the forward pump-room may be used for emptying the forward cofferdam. In each case, the suctions are to be led directly to the pump and not to a pipe system.

2.1.4 Cofferdams adjacent to the oil storage pump-room may be drained by an oil storage pump, provided that isolating arrangements are fitted in the bilge system, as required by Pt 5, Ch 15,2.2 of the Rules for Ships. In ship or barge-type units, a forward cofferdam may be drained by a bilge and ballast pump in a forward pump-room. Alternatively, cofferdams may be drained by bilge ejectors.

2.1.5 Cofferdams are not to have any direct connections to the oil storage tanks or lines, nor to designated non-hazardous machinery spaces.

2.1.6 Cofferdams separating safe spaces from oil storage tanks, cofferdams and other tanks within the range of the oil storage tanks, which are not intended for oil storage, are to be provided with air and sounding pipes led to the open deck. The air pipes are to be fitted with gauze diaphragms at their outlets.

2.1.7 So far as practicable, the air and sounding pipes required by 2.1.6 are not to pass through oil storage tanks. Where this cannot be avoided, the pipes are to be of steel having a wall thickness of not less than 12,5 mm and they are to be in continuous lengths or with welded or heavy flanged joints, the number of which is to be kept to a minimum.

2.1.8 Bilge, ballast and oil fuel lines, etc., which are connected to pumps, tanks or compartments at the ends of the ship outside hazardous zones and spaces, are not to pass through oil storage tanks or have any connections to oil storage tanks, or oil storage piping. No objection will be made to these lines being led through ballast tanks or void spaces within the range of the oil storage tanks.

2.1.9 The oil fuel bunkering system is to be entirely separate from the oil storage handling system.

2.1.10 Where non-permanent connections are required in piping systems between non-hazardous and hazardous spaces, two means of isolation are to be provided. One of these means is to provide positive separation by means of a removable spool piece or flexible hose, and blank flanges are to be fitted. The other is to be a non-return valve, or similar, in accordance with an acceptable National or International Standard that is appropriate for the design conditions of the piping system. The non-return valve and removable piece are to be located within the existing hazardous spaces. A notice is also to be provided located in a prominent position adjacent to the means of isolation, clearly indicating that the spool piece or flexible hose is to be removed, and blanking flanges are to be fitted, when the piping is not in use. The removable spool piece is to be clearly identified (labelled/painted in a distinctive colour) and stowed close to its working position.

2.2 Oil storage pump-room drainage

2.2.1 Provision is to be made for the bilge drainage of the oil storage pump-rooms by pump or bilge ejector suctions. The oil storage pumps or oil storage stripping pumps may be used for this purpose, provided that the bilge suctions are fitted with screw-down non-return valves and, in addition, an isolating valve or cock is fitted on the pump connection to the bilge chest. Pump-room suctions are not to enter machinery spaces.

2.3 Deep cofferdam drainage

2.3.1 Cofferdams, which are required to be provided at the fore and aft ends of the oil storage spaces in accordance with Pt 4, Ch 9,1.2 of the Rules for Ships are to be provided with suitable drainage arrangements. Examples of acceptable arrangements are detailed in 2.3.2 and 2.3.3.

2.3.2 Where deep cofferdams can be filled with water ballast, a ballast pump in the main engine room may be used for emptying the after cofferdam. Where fitted, a ballast pump in a forward pump-room may be used for emptying the forward cofferdam. In each case, the suctions are to be led direct to the pump and not to a pipe system.

2.3.3 Where intended to be dry compartments, after cofferdams adjacent to the pump-room may be drained by a oil storage pump, provided that isolating arrangements are fitted in the bilge system as required by 2.2.1, forward cofferdams may be drained by a bilge and ballast pump in a forward pump-room. Alternatively, cofferdams may be drained by bilge.

2.3.4 Cofferdams are not to have any direct connections to the oil storage tanks or oil storage lines.

2.4 Drainage of ballast tanks and void spaces within the range of the oil storage tanks

2.4.1 Ballast tanks and void spaces within the range of the oil storage tanks are not to be connected to oil storage pumps, or have any connections to the oil storage system. A separate ballast/bilge pump is to be provided for dealing with the contents of these spaces. This pump is to be located in the oil storage pump-room or other suitable space within the range of the oil storage tanks.

2.4.2 Ballast pumps shall be provided with suitable arrangements to ensure efficient suction from ballast tanks.

2.4.3 Where submerged water ballast pumps are fitted, they are to be located in separate compartments on opposite sides of the unit such that, in the event of hull damage due to grounding or collision, the risk of total loss of ballast pumping capability is minimised.

2.4.4 Ballast piping is not to pass through oil storage tanks and is not to be connected to stored oil piping. Provision may, however, be made for emergency discharge of water ballast by means of a portable spool connection to a stored oil pump and where this is arranged, a non-return valve is to be fitted in the ballast suction to the stored oil pump.

2.4.5 Consideration will be given to connecting double bottom and/or wing tanks, which are in the range of the oil storage tanks, to pumps in the machinery space where the tanks are completely separated from the cargo tanks by cofferdams, heating ducts or containment spaces, etc.

2.5 Air and sounding pipes

2.5.1 Deep cofferdams at the fore and aft ends of the oil storage spaces and other tanks or cofferdams within the range of the oil storage tanks, which are not intended for oil storage, are to be provided with air and sounding pipes led to the open deck. The air pipes are to be fitted with gauze diaphragms at their outlets.

2.5.2 The air and sounding pipes required by 2.5.1 are not to pass through oil storage tanks.

2.5.3 On oil storage units of less than 5000 tonnes deadweight, where wing ballast tanks or spaces are not required, the sounding and air pipes to double bottom spaces below oil storage tanks may pass through the oil storage tanks. However, the pipes are to be of heavy gauge steel, and are to be in continuous lengths or with welded joints.

2.6 Ballast piping in pump-room double bottoms

2.6.1 Ballast piping is permitted to be located within the oil storage pump-room double bottom provided any damage to that piping does not render the unit's ballast and oil storage pumps, located in the oil storage pump-room, ineffective.

■ *Section 3* Oil storage handling system

3.1 General

3.1.1 A complete system of piping and pumps is to be fitted for dealing with the stored oil.

3.1.2 Standby means for pumping out each oil storage tank are to be provided.

3.1.3 Where oil storage tanks are provided with single deep well pumps, or submerged pumps, it will be necessary to provide alternative means for emptying the tanks in the event of the failure of a pump. Portable submersible pumps may be provided on board for this purpose, but the arrangements are to be such that a portable pump could be safely introduced into a full or part-full tank. Details of the arrangements are to be submitted.

3.1.4 Provision is to be made for the gas freeing of the oil storage tanks when the stored oil has been discharged, and for the ventilation and gas freeing of all compartments adjacent to oil storage tanks. It is recommended that arrangements be provided to enable double bottom tanks situated below oil storage tanks to be filled with water ballast to assist in the gas freeing of these tanks, *see also* 7.6.2.

3.1.5 At least two portable instruments are to be available on board for gas detection.

3.1.6 Oil storage tank access hatches and all other openings to oil storage tanks, such as ullage and tank cleaning openings and restricted sounding devices, *see* 5.2, are to be located on the weather deck. For column-stabilised units, *see* Pt 3, Ch 3.

3.1.7 For requirements relating to control and supervision of unattended oil storage pumps located in dangerous or hazardous spaces, *see* Pt 7, Ch 2,5.

3.2 Oil storage pumps

3.2.1 Pumps for the purpose of filling or emptying the oil storage tanks are to be used exclusively for this purpose, except as provided in 2.2.1. They are not to have any connections to compartments outside the range of oil storage tanks.

3.2.2 Means are to be provided for stopping the oil storage pumps from a position outside the pump-rooms, as well as at the pumps.

3.2.3 The pumps are to be provided with effective relief valves which are to be in closed-circuit, i.e., discharging to the suction side of the pumps. Alternative proposals to safeguard against over-pressure on the discharge side of the pump will be specially considered.

3.2.4 Where oil storage pumps are driven by shafting which passes through a pump-room bulkhead or deck, gastight glands are to be fitted to the shaft at the pump-room plating. The glands are to be efficiently lubricated from outside the pump-room. The seal parts of the glands are to be of materials that will not initiate sparks. The glands are to be of an approved type and are to be attached to the bulkhead in accordance with Ch 13,2.4. Where a bellows piece is incorporated in the design, it is to be hydraulically tested to 3,4 bar (3,5 kgf/cm^2) before fitting.

3.2.5 Where oil storage pumps are driven by hydraulic motors which are located inside oil storage tanks, the design is to be such that contamination of the operating medium with cargo liquid cannot take place under normal operating conditions. The arrangements are to comply with 3.7.7 and 3.7.8, in so far as they are applicable.

3.3 Oil storage piping system

3.3.1 Oil storage piping and similar piping to oil storage tanks are not to pass through ballast tanks.

3.3.2 Oil storage pipes are not to pass through tanks or compartments which are outside the oil storage tank area.

3.3.3 Means are to be provided to enable the contents of the oil storage lines pumps to be drained to an oil storage tank or other suitable tank. Where drain tanks are fitted in pump-rooms, they are to be of the closed type with air and sounding pipes led to the open deck.

3.3.4 Expansion joints of approved type or bends are to be provided, where necessary, in the oil storage pipe lines.

3.3.5 Expansion pieces of an approved type, incorporating oil resistant rubber or other suitable material, may be accepted in oil storage piping, *see also* Ch 13,2.7.2.

3.3.6 Means are to be provided for keeping deck spills away from accommodation and service areas. This may be accomplished by means of a 300 mm coaming extending from side to side. Special consideration shall be given to the arrangements associated with stern loading.

3.3.7 Valves and fittings in the oil storage pipelines outside the tanks, and which incorporate elastomeric sealing materials, are to be fire-tested to an acceptable National Standard.

3.4 Terminal fittings at oil storage loading stations

3.4.1 Terminal pipes, valves and other fittings in the oil storage loading and discharging lines to which shore installation hoses are directly connected, are to be of steel or approved ductile material. They are to be of robust construction and strongly supported, *see also* 1.3 and 1.4.

3.4.2 A manually operated shut-off valve is to be fitted to each shore loading/discharging connection. In addition a blank flange, or equivalent arrangement, is to be provided at the pipeline end connections.

3.4.3 Drip pans for collecting residues in oil storage lines and hoses are to be provided beneath pipe and hose connections in the manifold area.

3.4.4 Loading and discharging hoses are to be a designed in accordance with acceptable recognised Standards. The selected hose is to be designed and constructed such that it is suitable for its intended purpose, taking into account pressure, temperature, fluid compatibility, mechanical loading and unit motions.

3.4.5 The loading hose string is to be provided with a weak link which is to be fitted with a self-sealing device.

3.4.6 Where an emergency quick-release system is fitted for the mooring system, an equivalent arrangement is to be provided to release the oil loading hose outboard of the unit.

3.4.7 Utility services, such as hydraulic and pneumatic systems, are to satisfy the requirements of Pt 5, Ch 14.

3.4.8 The area within 3 m from loading/discharge manifolds or pipe joints, and within 3 m of any spillage trays, is to be classified as a hazardous area as defined in Pt 7, Ch 2,1, *see also* Pt 7, Ch 2,2.

3.5 Bow or stern loading and discharge arrangements

3.5.1 Where a unit is arranged for bow and/or stern loading and discharge of oil outside the oil storage tank area, the pipe lines and related piping and equipment forward and/or aft of the oil storage area are to have only welded joints and are to be provided with spectacle flanges or removable spool pieces, where branched off from the main line, and a blank flange at the bow and/or stern end connections, irrespective of the number and type of valves in the line. The pipes are not to pass through enclosed spaces and are to be, as far as possible, self-draining.

3.5.2 The spaces within 4,5 m of flanged connections to, or valves or drip trays associated with, discharge manifolds are to be considered as hazardous spaces with regard to electrical or incendive equipment, *see also* Pt 6, Ch 2,14.10 of the Rules for Ships.

3.6 Connections to oil storage tanks

3.6.1 Where oil storage tanks are provided with direct filling connections, the loading pipes are to be led to as low a level as practicable inside the tank.

3.6.2 Where oil suction and/or filling lines are led through oil storage tanks, or through other spaces situated below the weather deck, the connection to each tank is to be provided with a valve situated inside the tank, and capable of being operated from the deck. In the case of oil storage tanks which are located adjacent to below-deck pump-rooms, or pipe tunnels, the deck operated valves may be located in these spaces at the bulkhead. In any case, not less than two isolating shut-off valves are to provided in the pipe lines between the tanks and the oil storage pumps.

3.7 Remote control valves

3.7.1 Valves on deck and in pump-rooms which are provided with remote control, are, in general, to be arranged for local manual operation independent of the remote operating mechanism, *see also* Ch 13,2.3.2 and 2.3.3.

3.7.2 Where the valves and their actuators are located inside the oil storage tanks, two separate suctions are to be provided in each tank, or alternative means of emptying the tank, in the event of a defective actuator, are to be provided.

3.7.3 All actuators are to be of a type which will prevent the valves from opening inadvertently in the event of the loss of pressure in the operating medium. Indication is to be provided at the remote control station showing whether the valve is open or shut.

3.7.4 Materials of construction of the actuators and piping inside the oil storage tanks are to be suitable for use with the intended oil.

3.7.5 Compressed air is not to be used for operating actuators inside oil storage tanks.

3.7.6 The actuator operating medium in hydraulic systems is to have a flash point of 60°C or above (closed-cup test) and is to be compatible with the intended oils.

3.7.7 The design of the actuators is to be such that contamination of the operating medium with stored oil cannot take place under normal operating conditions.

3.7.8 Where the operating medium is oil, or other fluid, the supply tank is to be located as high as practicable above the level of the top of the oil storage tanks, and all actuator supply lines are to enter the oil storage tanks through the highest part of the tanks. Furthermore, the supply tank is to be of the closed type with an air pipe led to a safe space on the open deck and fitted with a flameproof wire gauze diaphragm at its open end. This tank is also to be fitted with a high and low level audible and visual alarm. The requirements of this paragraph need not be complied with if the actuators and piping are located external to the oil storage tanks.

3.7.9 It is recommended that for remote control valves not arranged for manual operation, emergency means be provided for operating the valve actuators in the event of damage to the main hydraulic circuits on deck. In the case of valves located inside oil storage tanks, this could be achieved by ensuring that the supply lines to the actuators are led vertically inside the tanks from deck, and that connections, with necessary isolating valves, are provided on deck for coupling to a portable pump carried on board.

3.8 Oil storage handling controls

3.8.1 Electrical measuring, monitoring control and communication circuits located in hazardous spaces are to be in accordance with Pt 6, Ch 2,14.2 of the Rules for Ships, appropriate to the defined hazardous zone.

3.8.2 The handling controls and instruments are to be arranged for safe and easy operation. They may be grouped at a number of control stations or at one main control station.

3.8.3 A satisfactory means of communication is to be provided between oil storage handling stations, open deck, the bridge and the machinery space.

3.8.4 The oil storage handling controls and instrumentation are, so far as possible, to be separate from the propulsion and auxiliary machinery controls and instrumentation.

■ *Section 4*
Oil storage tank venting, purging and gas-freeing

4.1 Oil storage tank venting

4.1.1 The venting systems of oil storage tanks are to be entirely distinct from the air pipes of the other compartments of the unit. The arrangements and position of openings in the oil storage tank deck from which emission of flammable vapours can occur are to be such as to minimise the possibility of flammable vapours being admitted to enclosed spaces containing a source of ignition, or collecting in the vicinity of deck machinery and equipment which may constitute an ignition hazard.

4.1.2 The venting arrangements are to be so designed and operated as to ensure that neither pressure nor vacuum in oil storage tanks exceeds design parameters and are to be such as to provide for:

(a) the flow of the small volumes of vapour, air or inert gas mixtures caused by thermal variations in a oil storage tank in all cases through pressure/vacuum valves: and
(b) the passage of large volumes of vapour, air or inert gas mixtures during oil loading and ballasting, or during discharging.
(c) a secondary means of allowing full flow relief of vapour, air or inert gas mixtures to prevent overpressure or underpressure in the event of failure of the arrangements in 4.1.2(b). Alternatively, pressure sensors may be fitted to monitor the pressure in each tank protected by the arrangement required in 4.1.2(b), with a monitoring system in the unit's oil storage control room or the position from which oil storage operations are normally carried out. Such monitoring equipment is also to provide an alarm facility which is activated by detection of overpressure or underpressure conditions within a tank.

4.1.3 The venting arrangements in each oil storage tank may be independent or combined with other oil storage tanks and may be incorporated into the inert gas piping.

4.1.4 Where the arrangements are combined with other oil storage tanks either stop valves or other acceptable means are to be provided to isolate each oil storage tank. Where stop valves are fitted, they are to be provided with locking arrangements which are to be under the control of the responsible ship's officer.

4.1.5 There is to be a clear visual indication of the operational status of the valves, or other acceptable means. Where tanks have been isolated, it is to be ensured that the relevant isolating valves are opened before oil storage loading or ballasting or discharging of those tanks is commenced. Any isolation is to continue to permit the flow caused by thermal variations in a oil storage tank in accordance with 4.1.2(a).

4.1.6 If oil loading and ballasting or discharging of an oil storage tank or oil storage tank group, which is isolated from a common venting system is intended, that oil storage tank or oil storage tank group is to be fitted with a means for over-pressure or underpressure protection as required in 4.1.2(c).

4.1.7 The venting arrangements are to be connected to the top of each oil storage tank and are to be self-draining to the oil storage tanks under all normal conditions of trim and list of the unit. Where it may not be possible to provide self-draining lines permanent arrangements are to be provided to drain the vent lines to a oil storage tank.

4.1.8 The venting system is to be provided with devices to prevent the passage of flame into the oil storage tanks. The design, testing and locating of these devices are to comply with recognised International Standards.

4.1.9 Ullage openings are not to be used for pressure equalisation and they should be fitted with self-closing tightly sealing covers. Flame arrestors and screens are not permitted in these openings.

4.1.10 Provision is to be made to guard against liquid rising in the venting system to a height which would exceed the design head of oil storage tanks. This is to be accomplished by overflow control systems, or other equivalent means, e.g., overfill alarms, together with gauging devices and oil storage tank filling procedures but not spill valves which are not considered equivalent to an overflow system. The system for guarding against liquid rising to a height which would exceed the design head of oil storage tanks is to be independent of the gauging devices.

4.1.11 Openings for pressure release required by 4.1.2(a) are to:

(a) have as great a height as is practicable above the oil storage tank deck to obtain maximum dispersal of flammable vapours but in no case less than 2 m above the oil storage tank deck, and
(b) be arranged at the furthest distance practicable but not less than 5 m from the nearest air intakes and openings to enclosed spaces containing a source of ignition and from deck machinery, chain locker openings and equipment which may constitute an ignition hazard.

4.1.12 Pressure/vacuum valves required by 4.1.2(a) may be provided with a by-pass arrangement when they are located in a vent main or masthead riser. Where such an arrangement is provided there are to be suitable indicators to show whether the by-pass is open or closed.

4.1.13 Vent outlets for cargo loading, discharging and ballasting required by 4.1.2(b) are to:

(a) permit the free flow of vapour mixtures or alternatively, permit the throttling of the discharge of the vapour mixtures to achieve a velocity of not less than 30 m/sec;
(b) be so arranged that the vapour mixture is discharged vertically upwards;
(c) where the method is by free flow of vapour mixtures, be such that the outlet is not less than 6 m above the oil storage tank deck or fore and aft gangway if situated within 4 m of the gangway and located not less than 10 m measured horizontally from the nearest air intakes and openings to enclosed spaces containing a source of ignition and from deck machinery, chain locker openings and equipment which may constitute an ignition hazard;
(d) where the method is by high velocity discharge, be located at a height not less than 2 m above the oil storage tank deck and not less than 10 m measured horizontally from the nearest air intakes and openings to enclosed spaces containing a source of ignition and from deck machinery, chain locker openings and equipment which may constitute an ignition hazard. These outlets are to be provided with high velocity devices of an approved type; and
(e) be designed on the basis of the maximum designed loading rate multiplied by a factor of at least 1,25 to take account of gas evolution, in order to prevent the pressure in any oil storage tank from exceeding the design pressure. The master is to be provided with information regarding the maximum permissible loading rate for each oil storage tank and in the case of combined venting systems, for each group of oil storage tanks.

4.1.14 Pressure/vacuum valves are to be set at a positive pressure of not more than 0,2 bar (0,2 kgf/cm^2) above atmospheric and a negative pressure of not more than 0,07 bar (0,07 kgf/cm^2) below atmospheric. Higher positive pressures not exceeding 0,7 bar (0,7 kgf/cm^2) gauge may be permitted in specially designed integral tanks.

4.2 Oil storage tank purging and/or gas-freeing

4.2.1 Arrangements for purging and/or gas-freeing are to be such as to minimise the hazards due to the dispersal of flammable vapours in the atmosphere and to flammable mixtures in oil storage tank, thus the requirements of 4.2.2 to 4.2.4 are to be complied with, as applicable.

4.2.2 When the unit is provided with an inert gas system the oil storage tanks are first to be purged in accordance with the provisions of 7.6.2 until the concentration of hydrocarbon vapours in the oil storage tanks has been reduced to less than two per cent by volume. Thereafter gas freeing may take place at the oil storage tank deck level.

4.2.3 When the unit is not provided with an inert gas system, the operation is to be such that the flammable vapour is initially discharged either:

(a) through the vent outlets as specified in 4.1.13, or
(b) through outlets at least 2 m above the oil storage tank deck level with a vertical efflux velocity of at least 30 m/sec. maintained during gas freeing operation, or
(c) through outlets at least 2 m above the oil storage tank deck level with a vertical efflux velocity of at least 20 m/sec. and which are protected by suitable devices to prevent the passage of flame.

4.2.4 When the flammable vapour concentration at the outlet has been reduced to 30 per cent of the lower flammable limit, gas-freeing may thereafter be continued at the oil storage tank deck level.

4.3 Venting, purging and gas measurement of double hull and double bottom spaces

4.3.1 Double hull and double bottom spaces are to be fitted with suitable connections for the supply of air.

4.3.2 On oil storage units required to be fitted with inert gas systems:

(a) double hull spaces are to be fitted with suitable connections for the supply of inert gas;
(b) where such spaces are connected to a permanently fitted inert gas distribution system means are to be provided to prevent hydrocarbon gases from the oil storage tanks entering the double hull spaces through the system;
(c) where such spaces are not permanently connected to an inert gas distribution system, appropriate means are to be provided to allow connection to the inert gas main.

4.3.3 When selecting portable instruments for measuring oxygen and flammable vapour, due attention is to be given to their use in combination with the fixed gas sampling line systems referred to in 4.3.4.

4.3.4 Where the atmosphere in double hull spaces cannot be reliably measured using flexible gas sampling hoses, such spaces are to be fitted with permanent gas sampling lines. The configuration of such line systems is to be adapted to the design of such spaces.

4.3.5 The materials of construction and the dimensions of gas sampling lines are to be such as to prevent restriction. Where plastics materials are used, they are to be electrically conductive.

4.4 Gas measurement

4.4.1 All oil storage units are to be equipped with at least two portable instruments for measuring per cent LEL of hydrocarbon concentrations in air.

4.4.2 All oil storage units are to be equipped with at least two portable oxygen analysers.

4.4.3 For oil storage units fitted with an inert gas system two portable gas detectors capable of measuring flammable vapour concentrations in inerted atmospheres are to be provided, *see* 7.7.5.

4.4.4 Suitable means are to be provided for the calibration of gas measurement instruments.

■ *Section 5*
Oil storage tank level gauging equipment

5.1 General

5.1.1 Each oil storage tank is to be fitted with suitable means for ascertaining the liquid level in the tank in accordance with the requirements of 5.2 and 5.3.

5.2 Restricted sounding device

5.2.1 Sounding pipes or other approved devices, which may permit a limited amount of vapour to escape to atmosphere when being used, would be accepted for those tanks which are not required to be fitted with closed sounding devices, *see* 5.3. The devices are to be so designed as to minimise the sudden release of vapour or liquid under pressure and the possibility of liquid spillage on deck. Means are also to be provided for relieving tank pressure before the device is operated.

5.2.2 Separate ullage openings may be fitted as a reserve means for sounding oil storage tanks.

5.2.3 Arrangements which permit the escape of vapour to the atmosphere are not to be fitted in enclosed spaces.

5.3 Closed sounding devices

5.3.1 In all oil storage units fitted with a fixed inert gas system, the oil storage tanks are to be fitted with closed sounding devices of an approved type, which do not permit the escape of oil to the atmosphere when being used.

5.3.2 Proposals to use indirect sounding or measuring devices which do not penetrate the tank plating will be specially considered.

■ *Section 6*
Oil storage heating arrangements

6.1 General

6.1.1 Where heating systems are provided for the oil storage tanks, the arrangements are to comply with the requirements of 6.2 to 6.5.

6.2 Blanking arrangements

6.2.1 Spectacle flanges of spool pieces are to be provided in the heating medium supply and return pipes to the oil storage heating system, at a suitable position within the stored oil area, so that lines can be blanked off in circumstances where the cargo does not require to be heated or where the heating coils have been removed from the tanks. Alternatively, blanking arrangements may be provided for each tank heating circuit.

6.3 Heating circuits

6.3.1 The heating medium supply and return lines are not to penetrate the oil storage tank plating, other than at the top of the tank, and the main supply lines are to be run above the weather deck.

6.3.2 Isolating shut-off valves or cocks are to be provided at the inlet and outlet connections to the heating circuit(s) of each tank, and means are to be provided for regulating the flow.

6.3.3 Where steam or water is employed in the heating circuits, the returns are to be led to an observation tank which is to be in a well ventilated and well lighted part of the machinery space remote from the boilers.

6.3.4 Where a thermal oil is employed in the heating circuits, the arrangements will be specially considered but, in any case, they are to be such that contamination of the thermal oil with oil storage liquid cannot take place under normal operating conditions. In general, the arrangements are, at least, to comply with 3.7.8, in so far as they are applicable.

6.3.5 In any heating system, a higher pressure is to be maintained within the heating circuit than the maximum pressure head which can be exerted by the contents of the oil storage tank on the circuit. Alternatively, when the heating circuit is not in use, it may be drained and blanked.

6.4 Temperature indication

6.4.1 Means are to be provided for measuring the stored oil temperature. Where overheating could result in a dangerous condition, an alarm system which monitors the stored oil temperature is to be provided.

6.5 Thermal oil installations

6.5.1 The thermal oil system is normally to consist of a non-mix heat exchanger, one primary circuit heater and one secondary circulation system. The separate secondary thermal oil system arrangement for heating of the stored oil is to be located completely within the oil storage area. Alternatively, a single circuit system may be accepted, provided:

(a) the system is so arranged that a positive pressure in the heating coils is at least 3 m water gauge above the static head of the stored oil when the circulating pumps is not in operation;
(b) the thermal oil expansion tank is fitted with high and low level alarms;
(c) means are provided in the expansion tank for detection of flammable vapours from the stored oil;
(d) the valves for the individual heating coils are provided with locking arrangements to ensure that the coils are under static pressure at all times.

6.5.2 Each circulation system is to have two circulation pumps, one pump being in continuous operation and the other on standby, set to start up automatically on failure of the running pump. Each pump is to have sufficient capacity to ensure the required full-flow velocity in the heater tubes at all loads.

6.5.3 The circulation pumps are to be capable of being stopped in an emergency from a readily accessible location outside the compartment where they are situated.

6.5.4 Vents from thermal oil storage and expansion tanks are to be led to a safe location on the open deck and arranged with drainable flame arresters. Expansion tanks are to have overflow pipes leading to a suitable collecting tank.

6.5.5 Thermal oil heaters should normally be installed in separate compartments. Proposals for installation in engine rooms or other machinery rooms will be given special consideration in each case.

6.5.6 Stopping of oil burners, oil booster pumps and ventilation fans is to be possible from a readily accessible location outside the compartment where the thermal oil heaters are situated.

6.5.7 The inlet and outlet valves of oil-fired or exhaust fired heaters are to be controllable from outside the compartment, or alternatively, an arrangement for fast gravity discharge of the thermal oil to a separate collecting tank is to be provided.

6.5.8 The thermal oil heater outlet temperature is to be automatically controlled so as to keep the oil temperature within the limits of safe operation under all load conditions. It is to be ensured that the release of stored heat energy in the case of unintended stoppage of the thermal oil pumps will not cause the oil temperature to exceed the permissible level.

6.5.9 Exhaust-fired units are to be designed and installed so that all tubes can be readily inspected for corrosion or leakage.

6.5.10 When thermal oil heaters are fitted with automatic or remote controls so that under normal operating conditions they do not require any manual intervention by the operators, they are to be provided with the alarms and safety arrangements required by Table 15.6.1 as appropriate. Alternative arrangements which provide equivalent safeguards will be considered.

6.5.11 The design of the alarm, control and safety systems is to comply with the requirements of Pt 6, Ch 1,1.

Table 15.6.1 Alarms for thermal fluid heaters

Item	Alarm	Note
Expansion tank level	High and Low	Oil fuel burners to be shut off automatically
Thermal oil flow	Low	Oil fuel burners to be shut off automatically
Thermal oil pressure	Low	Oil fuel burners to be shut off automatically
Thermal oil outlet temperature	1st stage High	–
	2nd stage High	Oil fuel burners to be shut off automatically, see Pt 6, Ch 1,3.1.4
Combustion air pressure	Low	Oil fuel burners to be shut off automatically
Oil fuel pressure	Low	–
Oil fuel temperature or viscosity	High and low	Heavy oil only
Oil fuel atomising steam/air pressure	Low	–
Burner flame and ignition	Failure	Each burner to be monitored. Oil fuel burners to be shut off automatically, *see* Note 1
Uptake temperature	High	Where applicable, to monitor for soot fires

NOTES
1. Combustion spaces are to be purged automatically before re-ignition takes place in the event of a flame-out on all burners.
2. Special consideration may be given to the requirements for oil fired hot water heaters.

6.5.12 The standby pumps for oil fuel and thermal oil circulation are to start automatically when the discharge pressure from the working pump falls below a predetermined value.

6.5.13 The following heater services are to be fitted with automatic controls so as to maintain steady-state conditions throughout the operating range of the heater:
- Combustion system.
- Oil fuel supply temperature or viscosity, heavy oil only.
- Thermal oil temperature.

6.5.14 Any drain or vent valve is to be of self closing type and to be led directly to drain/expansion tank.

6.5.15 Relief valves are to be provided in closed circuit on all thermal fluid pumps.

6.5.16 Relief valve to be fitted on the outside of the fuel heaters.

6.5.17 Drain cocks or valves should be fitted to the bottom of oil fire boiler combustion chambers.

6.5.18 The self-ignition temperature or auto-ignition temperature of the thermal oil shall be at least 20 per cent higher than any hot surface that may be encountered by the oil should any item fail.

6.5.19 The oil should be non-toxic and should not give off toxic vapour in the event of fire or disassociation or decomposition.

6.5.20 Outlet valves on expansion tank to be fitted direct to the tank shell.

6.5.21 If the expansion tank is situated within a compartment the outlet valves are to be capable of being controlled from outside the compartment as per the Rules for Fuel Systems.

■ *Section 7*
Inert gas systems

7.1 General

7.1.1 The following requirements apply where an inert gas system, based on flue gas, is fitted on board units intended for the carriage of oil in bulk having a flash point not exceeding 60°C (closed-cup test). For inert gas systems utilising nitrogen, additional requirements contained in 7.9 are to be applied.

7.1.2 Units complying with these requirements will be eligible for the additional notation **IGS** on the ClassDirect Live website, *see* Pt 1, Ch 2.

7.1.3 Throughout this Section the term ‘oil storage tank’ includes also ‘slop tanks’. For definition of Machinery spaces of Category ‘A’, *see* SOLAS Reg. II-2/A.

7.1.4 The inert gas system is to comply with the requirements of Chapter 15 of the FSS Code, insofar as they are applicable, to new units only. For the purposes of classification any use of the word ‘Administration’ in the Regulation is to be taken as meaning LR.

7.1.5 Those parts of scrubbers, blowers, non-return devices, scrubber effluent and other drain pipes which may be subjected to corrosive action by the gases and/or liquids, are to be either constructed of corrosion resistant material or lined with rubber, glass fibre epoxy resin or other equivalent coating material.

7.1.6 The compartment in which any oil fired inert gas generator is situated is to be treated as a machinery space of Category A with respect to fire protection, *see also* Ch 1,4.8.

7.1.7 Arrangements are to be made to vent the inert gas from oil fired inert gas generators to the atmosphere when predetermined limits are reached, *see* 7.7.7(a) to (d), e.g., during start-up or in the event of equipment failure.

7.1.8 Automatic shut-down of the oil fuel supply to inert gas generators is to be arranged on predetermined limits being reached with respect to low water pressure or low water flow rate to the cooling and scrubbing arrangement and with respect to high gas temperature.

7.1.9 Automatic shut-down of the gas regulating valve is to be arranged with respect to failure of the power supply to the oil fired inert gas generators.

7.2 Gas supply

7.2.1 The inert gas may be treated flue gas from the main or auxiliary boiler(s), gas turbine(s), or from a separate inert gas generator. In all cases, automatic combustion control, capable of producing suitable inert gas under all service conditions, is to be fitted.

7.2.2 Two oil fuel pumps are to be fitted to the inert gas generator. One fuel pump only may be accepted provided sufficient spares for the oil fuel pump and its prime mover are carried on board to enable any failure of the oil fuel pump and its prime mover to be rectified by the unit's crew.

7.2.3 The inert gas system is to be capable of:

(a) inerting empty oil storage tanks by reducing the oxygen content of the atmosphere in each tank to a level at which combustion cannot be supported;

(b) maintaining the atmosphere in any part of any oil storage tank with an oxygen content not exceeding eight per cent by volume and at a positive pressure at all times in port and at sea except when it is necessary for such a tank to be gas free;

(c) eliminating the need for air to enter a tank during normal operations except when it is necessary for such a tank to be gas free;

(d) purging empty oil storage tanks of hydrocarbon gas, so that subsequent gas freeing operations will at no time create a flammable atmosphere within the tank.

7.2.4 The system is to be capable of delivering inert gas to the oil storage tanks at a rate of at least 125 per cent of the maximum rate of discharge capacity of the unit expressed as a volume to time rate.

7.2.5 The system is to be capable of delivering inert gas with an oxygen content of not more than five per cent by volume in the inert gas supply main to the oil storage tanks at any required rate of flow.

7.2.6 Flue gas isolating valves are to be fitted in the inert gas supply mains between the boiler uptakes and the flue gas scrubber. These valves are to be provided with indicators to show whether they are open or shut, and precautions are to be taken to maintain them gastight and keep the seatings clear of soot. Arrangements are to be made to ensure that boiler soot blowers cannot be operated when the corresponding flue gas valve is open.

7.3 Gas scrubber

7.3.1 A flue gas scrubber is to be fitted which will effectively cool the volume of gas specified in 7.2.4 and remove solids and sulphur combustion products. The cooling water arrangements are to be such that an adequate supply of water will always be available without interfering with any essential services on the unit. Provision is also to be made for alternative supply of cooling water.

7.3.2 Filters or equivalent devices are to be fitted to minimise the amount of water carried over to the inert gas blowers.

7.3.3 The scrubber is to be located aft of all oil storage tanks, oil storage pump-rooms and cofferdams separating these spaces from machinery spaces of Category A.

7.4 Gas blowers

7.4.1 At least two blowers are to be fitted which together are capable of delivering to the oil storage tanks at least the volume of gas required by 7.2.4. In no case is one of these blowers to have a capacity less than one third of the total capacity required. In a system with gas generators one blower only may be accepted if that system is capable of delivering the total volume of gas required by 7.2.4 to the protected oil storage tanks, provided that sufficient spares for the blower and its prime mover are carried on board to enable any failure of the blower and its prime mover to be rectified by the unit's crew.

7.4.2 The inert gas system is to be so designed that the maximum pressure which it can exert on any oil storage tank will not exceed the test pressure of any oil storage tank. Suitable shut-off arrangements are to be provided on the suction and discharge connections of each blower. Arrangements are to be provided to enable the functioning of the inert gas plant to be stabilised before commencing oil storage discharge. If the blowers are to be used for gas freeing, their air inlets are to be provided with blanking arrangements.

7.4.3 The blowers are to be located aft of all oil storage tanks, cargo pump-rooms and cofferdams separating these spaces from machinery spaces of Category A.

7.5 Gas distribution lines

7.5.1 Special consideration is to be given to the design and location of scrubber and blowers with relevant piping and fittings in order to prevent flue gas leakages into enclosed spaces.

7.5.2 To permit safe maintenance, an additional water seal or other effective means of preventing flue gas leakage is to be fitted between the flue gas isolating valves and scrubber or incorporated in the gas entry to the scrubber.

7.5.3 A gas regulating valve is to be fitted in the inert gas supply main. This valve is to be automatically controlled to close as required in 7.7.9 and 7.7.10. It is also to be capable of automatically regulating the flow of inert gas to the oil storage tanks unless means are provided to automatically control the speed of the inert gas blowers required in 7.4.1.

7.5.4 The valve referred to in 7.5.3 is to be located at the forward bulkhead of the forwardmost gas safe space through which the inert gas supply main passes.

7.5.5 At least two non-return devices, one of which is to be a water seal, are to be fitted in the inert gas supply main, in order to prevent the return of hydrocarbon vapour to the machinery space uptakes or to any gas safe spaces under all normal conditions of trim, list and motion of the unit. They are to be located between the automatic valve required by 7.5.3 and the aftermost connection to any oil storage unit tank or oil storage pipeline.

7.5.6 The devices referred to in 7.5.5 are to be located in the oil storage area on deck.

7.5.7 The water seal referred to in 7.5.5 is to be capable of being supplied by two separate pumps, each of which is to be capable of maintaining an adequate supply at all times.

7.5.8 The arrangement of the seal and its associated fittings is to be such that it will prevent backflow of hydrocarbon vapours and will ensure the proper functioning of the seal under operating conditions.

7.5.9 Provision is to be made to ensure that the water seal is protected against freezing in such a way that the integrity of seal is not impaired by overheating.

7.5.10 A water loop or other approved arrangement is also to be fitted to each associated water supply and drain pipe and each venting or pressure-sensing pipe leading to gas safe spaces. Means are to be provided to prevent such loops from being emptied by vacuum.

7.5.11 The deck water seal and all loop arrangements are to be capable of preventing return of hydrocarbon vapours at a pressure equal to the test pressure of the oil storage tanks.

7.5.12 The second non-return device is to be a non-return valve or equivalent capable of preventing the return of vapours or liquids and fitted forward of the deck water seal required in 7.5.5. It is to be provided with positive means of closure. As an alternative to positive means of closure, an additional valve having such means of closure may be provided forward of the non-return valve to isolate the deck water seal from the inert gas main to the oil storage tanks.

7.5.13 As an additional safeguard against the possible leakage of hydrocarbon liquids or vapours back from the deck main, means are to be provided to permit this section of the line between the valve having positive means of closure referred to in 7.5.12 and the valve referred to in 7.5.3 to be vented in a safe manner when the first of these valves is closed.

7.5.14 The inert gas main may be divided into two or more branches forward of the non-return devices required by 7.5.5.

7.5.15 The inert gas supply mains are to be fitted with branch piping leading to each oil storage tank. Branch piping for inert gas is to be fitted with either stop valves or equivalent means of control for isolating each tank. Where stop valves are fitted, they are to be provided with locking arrangements, which are to be under the control of a responsible unit's officer. The method of control is to provide positive indication of the operational status of such valves.

7.5.16 Means are to be provided to protect oil storage tanks against the effect of overpressure or vacuum caused by thermal variations when the oil storage tanks are isolated from the inert gas mains.

7.5.17 Piping systems are to be so designed as to prevent the accumulation of oil or water in the pipelines under all normal conditions.

7.5.18 Arrangements are to be provided to enable the inert gas main to be connected to an external supply of inert gas. The arrangement is to consist of a 250 mm nominal size pipe bolted flange connection, isolated from the inert gas main by a valve and connected to the system forward of the non-return valve referred to in 7.5.12.

7.6 Venting arrangements

7.6.1 The arrangements for the venting of all vapours displaced from the oil storage tanks during loading and ballasting are to comply with Section 4 and are to consist of either one or more mast risers, or a number of high velocity vents. The inert gas supply mains may be used for such venting.

7.6.2 The arrangements for inerting, purging or gas freeing of empty tanks as required in 7.2.3 are to be such that the accumulation of hydrocarbon vapours in pockets formed by the internal structural members in a tank is minimised and that:

(a) on individual oil storage tanks the gas outlet pipe, if fitted, is to be positioned as far as practicable from the inert gas/air inlet and in accordance with Section 4. The inlet of such outlet pipes may be located either at deck level or at not more than 1 m above the bottom of the tank;
(b) the cross-sectional area of such gas outlet pipes referred to in (a) is to be such that an exit velocity of at least 20 m/s can be maintained when any three tanks are being simultaneously supplied with inert gas. Their outlets are to extend not less than 2 m above deck level;
(c) each gas outlet referred to in (b) is to be fitted with suitable blanking arrangements;
(d) if a connection is fitted between the inert gas supply mains and the oil storage piping system, arrangements are to be made to ensure an effective isolation having regard to the large pressure difference which may exist between the systems. This is to consist of two shut-off valves with an arrangement to vent the space between the valves in a safe manner or an arrangement consisting of a spool-piece with associated blanks. The valve separating the inert gas supply main from the oil storage transfer main and which is on the oil storage transfer main side is to be a non-return valve with a positive means of closure.

7.6.3 One or more pressure-vacuum breaking devices are to be provided to prevent the oil storage tanks from being subject to:

(a) a positive pressure in excess of the test pressure of the oil storage tank if the oil were to be loaded at the maximum rated capacity and all other outlets were left shut; and

(b) a negative pressure in excess of 700 mm water gauge if oil were to be discharged at the maximum rated capacity of the oil storage transfer pumps and the inert gas blowers were to fail.

Such devices shall be installed on the inert gas main unless they are installed in the venting system required by Section 4 or on individual oil storage tanks.

7.6.4 The location and design of the devices referred to in 7.6.3 are to be in accordance with Section 4.

7.7 Instrumentation and alarms

7.7.1 Means are to be provided for continuously indicating the temperature and pressure of the inert gas at the discharge side of the gas blowers, whenever the gas blowers are operating.

7.7.2 Instrumentation is to be fitted for continuously indicating and permanently recording, when the inert gas is being supplied:

(a) the pressure of the inert gas supply mains forward of the non-return devices required by 7.5.5; and

(b) the oxygen content of the inert gas in the inert gas supply mains on the discharge side of the gas blowers.

7.7.3 The devices referred to in 7.7.2 are to be placed in the oil storage control room where provided. But where no oil storage control room is provided, they are to be placed in a position easily accessible to the officer in charge of oil storage operations.

7.7.4 In addition to 7.7.2, meters are to be fitted:

(a) in the navigating bridge to indicate at all times the pressure referred to in 7.7.2(a); and

(b) in the machinery control room or in the machinery space to indicate the oxygen content referred to in 7.7.2(b).

7.7.5 Portable instruments for measuring oxygen and flammable vapour concentration are to be provided. In addition, suitable arrangement is to be made on each oil storage tank such that the condition of the tank atmosphere can be determined using these portable instruments.

7.7.6 Suitable means are to be provided for the zero and span calibration of both fixed and portable gas concentration measurement instruments, referred to in 7.7.2, 7.7.4 and 7.7.5.

7.7.7 For inert gas systems of both flue gas type and the inert gas generator type audible and visual alarms are to be provided to indicate:

(a) low water pressure or low water flow rate to the flue gas scrubber as referred to in 7.3.1;

(b) high water level in the flue gas scrubber as referred to in 7.3.1;

(c) high gas temperature as referred to in 7.7.1;

(d) failure of the inert gas blowers referred to in 7.4;

(e) oxygen content in excess of eight per cent by volume as referred to in 7.7.2(b);

(f) failure of the power supply to the automatic control system for the gas regulating valve and to the indicating devices as referred to in 7.5.3 and 7.7.2;

(g) low water level in the water seal as referred to in 7.5.5;

(h) gas pressure less than 100 mm water gauge as referred to in 7.7.2(a); and

(j) high gas pressure as referred to in 7.7.2(a).

7.7.8 For inert gas systems of the inert gas generator type additional audible and visual alarms are to be provided to indicate:

(a) insufficient oil fuel supply;

(b) failure of the power supply to the generator;

(c) failure of the power supply to the automatic control system for the generator.

See also Pt 6, Ch 1 for requirements for control, alarm and safety systems, and additional requirements for unattended operation.

7.7.9 Automatic shutdown of the inert gas blowers and gas regulating valve is to be arranged on predetermined limits being reached in respect of (a), (b) and (c) of 7.7.7.

7.7.10 Automatic shutdown of the gas regulating valve is to be arranged in respect of 7.7.7(d).

7.7.11 In respect of 7.7.7(e), when the oxygen content of the inert gas exceeds eight per cent by volume, immediate action is to be taken to improve the gas quality. Unless the quality of the gas improves, all oil storage tank operations are to be suspended so as to avoid air being drawn into the tanks and the isolation valve referred to in 7.5.12 is to be closed.

7.7.12 The alarms required in (e), (f) and (h) of 7.7.7 are to be fitted in the machinery space and oil storage control room, where provided, but in each case in such a position that they are immediately received by responsible members of the crew.

7.7.13 In respect of 7.7.7(g), where a semi-dry or dry water seal is fitted, the arrangements are to be such that the maintenance of an adequate reserve of water will be ensured at all times and that the water seal will be automatically formed when the gas flow ceases. The audible and visual alarm on the low level of water in the water seal is to operate when the inert gas is not being supplied.

7.7.14 An audible alarm system independent of that required in 7.7.7(h) or automatic shutdown of stored oil pumps is to be provided to operate on predetermined limits of low pressure in the inert gas mains being reached.

7.7.15 Detailed instruction manuals are to be provided on board, covering the operations, safety and maintenance requirements and occupational health hazards relevant to the inert gas system and its application to the oil storage tank system. The manuals are to include guidance on procedures to be followed in the event of a fault or failure of the inert gas system.

7.8 Installation and tests

7.8.1 The inert gas system, including alarms and safety devices, is to be installed on board and tested under working conditions to the satisfaction of the Surveyors.

7.9 Nitrogen generator systems

7.9.1 The following requirements are specific only to the gas generator system and apply where inert gas is produced by separating air into its component gases by passing compressed air through a bundle of hollow fibres, semi-permeable membranes or adsorber materials.

7.9.2 Where nitrogen generator systems are provided in place of boiler flue gas or oil fired inert gas generators referred to in 7.1, the following requirements of Chapter 15 of the FSS Code remain applicable for the piping arrangements, alarms and instrumentation downstream of the gas generator: 2.3.1.3.1, 2.3.1.3.2, 2.3.1.5, 2.3.2, 2.4.2, 2.4.3.1.6, 2.4.3.1.8, 2.4.3.1.9, 2.4.3.3, 2.4.3.4, 2.4.4, as well as SOLAS Reg.II-2/4.5.3.4.2, 4.5.6.3 and 11.6.3.4.

7.9.3 A nitrogen generator consisting of a feed air treatment system and any number of membrane or adsorber modules in parallel is to be capable of delivering nitrogen to the oil storage tanks at a rate of at least 125 per cent of the maximum discharge capacity of the unit expressed as a volume to time rate.

7.9.4 The air compressor and the nitrogen generator may be installed in the engine room or in a separate compartment, which may be treated as an 'other machinery space' with respect to fire protection.

7.9.5 Where a separate compartment is provided, it is to be positioned outside the oil storage area and is to be fitted with an independent mechanical extraction ventilation system providing at least 6 air changes per hour. The compartment is to have no direct access to accommodation spaces, service spaces and control stations, and is to be provided with oxygen level detection equipment with a low oxygen level alarm.

7.9.6 The nitrogen generator is to be capable of delivering high purity nitrogen with oxygen content not exceeding 5 per cent by volume. The system is to be fitted with automatic means to discharge gas to the atmosphere during start-up and abnormal operation when predetermined limits are reached, *see* 7.9.16(a) to (e).

7.9.7 The system is to be provided with two air compressors. The total required capacity of the system is preferably to be divided equally between the two compressors, and in no case is one compressor to have a capacity less than 1/3 of the total capacity required. A system with one air compressor only may be accepted provided that sufficient spares for the air compressor and its prime mover are carried on board to enable their failure to be rectified by the unit's crew.

7.9.8 A feed air treatment system is to be fitted to remove free water, particles and traces of oil from the compressed air, and to maintain the specification temperature.

7.9.9 Where a nitrogen receiver/buffer tank is required to be fitted it may be installed in a dedicated compartment or in the separate compartment containing the air compressor and the generator or may be located in the oil storage area. Where the nitrogen receiver/buffer tank is installed in an enclosed space, the access is to be arranged from the open deck only and the access door is to open outwards. Permanent ventilation and alarm arrangements are to be fitted as required by 7.9.5.

7.9.10 The oxygen-enriched air from the nitrogen generator and the nitrogen-product enriched gas from the protective devices of the nitrogen receiver are to be arranged to discharge to a safe location on the open deck.

7.9.11 In order to permit maintenance, means of isolation are to be fitted between the generator and the receiver.

7.9.12 At least two non-return devices are to be fitted in the inert gas supply main, one of which is to be of the double block and bleed arrangement. The second non-return device is to be equipped with positive means of closure.

7.9.13 Instrumentation is to be provided for continuously indicating the temperature and pressure of air:

(a) at the discharge of the compressor,
(b) at the inlet to the nitrogen generator.

7.9.14 Instrumentation is to be fitted for continuously indicating and permanently recording the oxygen content of the inert gas downstream of the nitrogen generator when inert gas is being supplied.

7.9.15 The instrumentation referred to in 7.9.14 is to be placed in the oil storage control room where provided. Where no control room is provided, the instrumentation is to be placed in a position easily accessible to the officer in charge of oil storage operations.

7.9.16 Audible and visual alarms are to be provided to indicate:

(a) low feed-air pressure from compressor as referred to in 7.9.13(a),
(b) high air temperature as referred to in 7.9.13(a),
(c) high condensate level at automatic drain of water separator as referred to in 7.9.8,
(d) failure of electrical heater, if fitted,
(e) oxygen content in excess of that required in 7.9.6,
(f) failure of power supply to the instrumentation as referred to in 7.9.14.

7.9.17 Automatic shut-down of the system is to be arranged upon alarm conditions as required by 7.9.16(a) to (e).

7.9.18 The alarms required by 7.9.16(a) to (f) are to be fitted in the machinery space and oil storage control room, where provided, but in each case in such a position that they are immediately received by responsible members of the crew.

7.10 Nitrogen/inert gas systems fitted for purposes other than inerting required by SOLAS Reg. II-2/4.5.5.1

7.10.1 This Section applies to systems fitted on oil storage units of less than 20000 DWT.

7.10.2 The requirements of 7.9 apply except paragraphs 7.9.1, 7.9.2, 7.9.3 and 7.9.7.

7.10.3 Where the connection to the oil storage tanks, to the cargo piping is not permanent, the non-return devices required by 7.9.12 may be substituted by two non-return valves.

■ *Cross-reference*

For vapour detection, *see also* Ch 13,2 of the *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquid Chemicals in Bulk.*

Section

1 **General requirements**

■ *Section 1*
General requirements

1.1 General

1.1.1 Gas from the unit's process plant may be utilised as fuel in gas turbines/engines and auxiliary boilers/fired heaters, and crude oil/slops may be used in auxiliary boilers/fired heaters, provided the requirements of this Chapter are complied with. Diagrammatic plans showing ventilation arrangements, piping system layout and safety devices should be submitted for approval in each case.

1.1.2 Boilers, turbines, etc., which are arranged for burning gas or crude oil/slops are to be located within designated non-hazardous areas such as a boiler or turbine room or enclosure.

1.1.3 The design and construction of turbines, boilers, burners, etc., is to be suitable for operation on gas or crude oil as appropriate, effectively maintaining stable and complete combustion under all operating conditions.

1.1.4 The design of gas-burning internal combustion reciprocating engines and turbines will be specially considered in each case. For special requirements relating to boilers/fired heaters burning gas or crude oil/slops, *see* 1.6.

1.1.5 Consideration will be given to special cases or to arrangements which are equivalent to those required by these Rules.

1.2 Fuel gas supply arrangements

1.2.1 Gas which is taken directly from the process plant is to be treated before distribution. The system should include suitable treatment equipment to provide well-mixed, liquid-free gas at constant pressure.

1.2.2 The gas treatment system is to be located within a designated hazardous area. This area is to be separated from the boiler room or machinery space by a gas-tight bulkhead.

1.2.3 Liquid drains from the treatment equipment are to be led to a closed drain recovery system. Gas lines downstream of the treatment equipment should be heat traced or insulated as necessary to prevent condensation and hydrate formation.

1.2.4 A separate and independent gas supply line is to be provided for each gas burning unit and each line is to be provided with a fuel gas master valve arranged to close automatically if gas leakage is detected, or on loss of the required ventilation from the pipe duct or casing, or loss of pressurisation of the double-walled piping, *see* 1.4.2.

1.2.5 The fuel gas master valves and pressure regulators/reducing valves are to be located external to the boiler room or machinery space.

1.2.6 The gas supply line to each gas burning unit is to be fitted with a double block-and-bleed system utilising three automatic valves comprising two valves in series enabling the gas supply to be shut off and vented via a third valve to atmosphere at a safe location. These valves are to be arranged so that failure of the required ventilation, flame failure at the burners, abnormal gas supply pressure or loss of the valve actuating medium will cause the two valves in series to close and the vent valve between them to open. The valves are to be arranged for manual reset.

1.2.7 All master valves and block-and-bleed valves are to be arranged for remote operation from a location outside the boiler room or machinery space, and for local operation from the boiler or turbine control console.

1.2.8 The operation of the master valves or block-and-bleed valves is to activate an alarm in the machinery space and in the central control room.

1.2.9 For long runs of high pressure gas piping, consideration should be given to the fitting of a self-closing 'safety block valve' between adjoining all-welded sections of piping, which would automatically isolate the gas supply in cases of pipe fracture.

1.2.10 Provision is to be made for gas-freeing and inerting that portion of the fuel gas piping system located in the boiler room or machinery space.

1.2.11 Suitable arrangements are to be made for change over between gas and oil fuel so that change over can be accomplished quickly and easily.

1.3 Crude oil supply arrangements

1.3.1 Crude oil or slops may be taken directly from the unit's storage tanks, or from other suitable tanks. Such tanks are to be separated from non-hazardous areas by means of cofferdams with gas-tight bulkheads. Where crude oil/slops in tanks is preheated, its temperature is to be automatically controlled and a high temperature alarm and cut-out fitted.

1.3.2 The crude oil/slops transfer and treatment system (pumps, strainers, separators, etc.) is to be located within a designated hazardous area, such as a pump-room. This area is to be separated from the boiler room and other machinery spaces by gas-tight bulkheads.

1.3.3 Where crude oil/slops is heated by steam or hot water, the outlet from the heating coils is to be led to a separate, closed observation tank located within a designated hazardous area, together with the transfer and treatment components. This tank is to be fitted with a vent pipe led to atmosphere at a safe location, and the vent outlet fitted with a suitable flame arrester.

1.3.4 Pumps are to be fitted with a pressure relief valve in closed circuit discharging to the suction side, and are to be capable of being stopped from the machinery control room and from near the boiler front, as well as locally in the compartment in which they are situated.

1.3.5 Prime movers for pumps, etc., (excluding hydraulic motor drives) are to be located in a non-hazardous machinery space. Where drive shafts pass through a pump-room bulkhead or deck, gas-tight glands are to be fitted. These glands are to be effectively lubricated from outside the pump-room, *see also* Pt 5, Ch 15,3.2.4.

1.3.6 The crude oil piping is, as far as practicable, to be installed with an inclination rising towards the boiler so that the oil naturally returns towards the pumps in the case of leakage or failure in delivery pressure.

1.3.7 Crude oil delivery and return pipes are to be fitted with fail-close, shut-off master valves located external to the boiler room and remotely controlled from a position near the boiler fronts and from the machinery control room. These valves are to be arranged to close automatically on failure of duct ventilation or on detection of crude oil leakage within the duct.

1.3.8 The crude oil supply line to each burner unit is to be fitted with an automatic shutdown valve arranged so that failure of the forced draught fan, boiler hood exhaust fan, flame failure at the burner or loss of the valve actuating medium will cause the valve to close. The valves are to be arranged for local operation and for manual reset.

1.3.9 The operation of the master valves or burner shutdown valves is to activate an alarm in the boiler room and in the central control room.

1.3.10 Provision is to be made for gas-freeing and inerting that portion of the crude oil piping system located in the boiler room or machinery space.

1.3.11 Suitable arrangements are to be made for change over between crude oil/slops and oil fuel so that change over can be accomplished quickly and easily.

1.4 Piping requirements

1.4.1 Fuel gas and crude oil piping is to be entirely separate from other piping systems and is not to pass through accommodation, service spaces or control stations. Such piping within the boiler room or machinery space is to be enclosed in a ventilated, gas-tight duct or be doublewalled as per either 1.4.2 or 1.4.3 respectively. For piping external to the boiler room or machinery space, or passing through enclosed non-hazardous spaces, *see* 1.4.6.

1.4.2 The piping is to be installed within a ventilated, gas-tight duct, and this duct is to be connected to the bulkhead where it enters the boiler room or machinery space and to the burner unit(s) enclosure. The duct is to be provided with mechanical ventilation having a capacity of at least 30 air changes per hour and arranged to maintain a pressure less than atmospheric pressure. The ventilation outlet is to be located at a safe location where no gas-air mixture could be ignited. The duct ventilation is to be in continuous operation when fuel is in the piping. Continuous gas monitoring is to be provided in the duct to detect leaks, and arranged to automatically close the master valve in accordance with 1.2.4 or 1.3.7.

1.4.3 Alternatively, the piping may be a double-walled piping system with the fuel contained in the inner pipe and the annular space between pipes pressurised with inert gas to a pressure greater than the fuel pressure. Alarms are to be provided to indicate loss of pressure between the pipes and the master valves arranged to automatically close in accordance with 1.2.4 or 1.3.7.

1.4.4 Piping connections are to be reduced to the minimum required for installation and machinery maintenance. All piping is to be suitably and adequately supported so as to avoid vibration.

1.4.5 The piping for conveying fuel gas or crude oil/slops, and for the drainage pipes from the tray specified in 1.6.3, is to have a minimum wall thickness as specified for oil fuel systems in Chapter 12.

1.4.6 Gas and crude oil/slops supply and return pipes which are located external to the boiler room or machinery space in open or semi-enclosed non-hazardous areas are to be of seamless heavy gauge steel with a minimum wall thickness of Sch 80, and have fully radiographed, full penetration, butt welded joints. Pipe connections are to be of the heavy flange type. This piping is to be clearly identifiable by means of a suitable colour code. Piping passing through enclosed non-hazardous spaces will be specially considered.

1.5 Boiler room and machinery space ventilation

1.5.1 Ventilation of the boiler rooms and machinery spaces is to be at a pressure above atmospheric pressure by a separate ventilation system independent of all other ventilation systems, and providing at least 12 air changes per hour. At least two 100 per cent capacity fans are to be fitted. If the boiler, turbine, etc., is installed in a confined part of the boiler room or machinery space, the ventilation requirements apply to that part of the space only. For particular requirements relating to gas turbine ventilation, *see* Pt 7, Ch 2,6.5.

1.5.2 The ventilation system is to ensure good air circulation in all spaces, and in particular to prevent the formation of stagnant pockets of gas within the space. Gas detectors are to be fitted at appropriate locations in these spaces, particularly where air circulation may be restricted.

1.5.3 Where released gases are likely to be heavier than air as in the case of crude oil systems, extraction ducts should be located at a low level within the boiler room. Open mesh floor plates should be utilised as required to ensure efficient extraction of gases.

1.5.4 The ventilation air intakes are to be from an external non-hazardous area, at least 3 m from the boundary of any hazardous area. Ventilation outlets are to be led to atmosphere at a safe location.

1.5.5 Boilers and turbines are to be fitted with a suitable hood or casing, arranged so as to enclose as much as possible of the burners and associated valves and pipes, but without restricting the air flow to the burner registers. The hood or casing should be installed to ensure that the ventilating air sweeps across the enclosed valves, etc., and be fitted with doors as necessary for inspection of, and access to, the burner units, valves and pipes.

1.5.6 The boiler/turbine hood is to be fitted with a ventilation duct led to atmosphere at a safe location, and with the vent outlet fitted with a suitable flame-proof wire gauze. At least two 100 per cent capacity extraction fans with spark-proof impellers are to be fitted to maintain the pressure inside the hood less than that of the boiler room or machinery space. The fans are to be arranged for automatic change over to the standby fan on failure of the operational fan. The fan prime movers are to be placed outside the duct with gas-tight drive shaft penetration through the duct casing.

1.5.7 Means of continuous gas detection is to be provided in way of the hood and gas pipe ducting and arranged to provide an audible and visual alarm at 30 per cent lower explosive limit and shut-down of the fuel supply before the gas concentration reaches 60 per cent of the lower explosive limit.

1.6 Special requirements for boilers/fired heaters

1.6.1 The arrangement of boilers and burner systems is to comply, in general, with the requirements of Chapter 14, as applicable. The whole of the boiler casing is to be gas-tight and each boiler is to have a separate uptake.

1.6.2 The arrangement of burner units and all associated valves is to be such that the fuel gas or crude oil/slops is ignited by the flame of the oil fuel burner. A flame scanner is to be installed and arranged to ensure that the fuel supply to the burner is cut off unless satisfactory ignition has been established and maintained. A manually operated shut-off valve and flame arrester is to be fitted to each burner unit.

1.6.3 Boilers for burning crude oil/slops are to be fitted with a tray or gutterway of suitable height placed in such a way so as to collect any possible oil leakage from burners, valves or connections. The tray or gutterway is to be fitted with a drain pipe discharging into a separate, closed collecting tank in the boiler room, pump-room or other suitable location. This tank is to be fitted with a vent pipe led to atmosphere at a safe location, and with the vent outlet fitted with a suitable flame arrester, and with provision for drainage to a suitable tank outside the machinery space.

1.6.4 Means are to be provided for the boiler to be automatically purged before firing or relighting. Arrangements are also to be provided to allow manual purging, but interlocking devices should be fitted to ensure that purging can only be carried out when the burner fuel supply valves are closed.

Requirements for Fusion Welding of Pressure Vessels and Piping

■ *Section 1* General

1.1 Scope

1.1.1 The requirements of this Chapter apply to the welding of pressure vessels and process equipment, heating and steam raising boilers and pressure pipes. The allocation of Class is determined from the design criteria referenced in Chapters 10, 11 and 12.

1.1.2 Fusion welded pressure vessels will be accepted only if manufactured by firms equipped and competent to undertake the quality of welding required for the Class of vessel proposed. For Class 1, 2/1 and 2/2 pressure vessels, the manufacturer's works are to be approved in accordance with the requirements specified in *Materials and Qualification Procedures for Ships*, *Book A Procedure MQPS 0-4*.

1.1.3 For pressure vessels which only have circumferential seams, *see* Ch 10,1.5.4 and Ch 11,1.5.5.

1.2 General requirements for welding plant and welding quality

1.2.1 In the first instance, and before work is commenced, the Surveyors are to be satisfied that the required quality of welding is attainable with the proposed welding plant, equipment and procedures in accordance with the guidelines specified in *Materials and Qualification Procedures for Ships Book A, Procedure 0-4.*

1.2.2 All welding is to be in accordance with the requirements specified in Chapter 13 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

1.3 Manufacture and workmanship of fusion welded pressure vessels

1.3.1 Pressure vessels are to be constructed and examined in accordance with the requirements specified in Chapter 13 of the Rules for Materials, unless more stringent requirements are specified.

■ *Section 2* Manufacture and workmanship of fusion welded pressure vessels

2.1 General requirements

2.1.1 Prior to commencing construction, the design of the vessel is to be approved where required by Ch 10,1.6 and Ch 11,1.6.

2.1.2 Pressure vessels will be accepted only if manufactured by firms that have been assessed and approved in accordance with MQPS 0-4.

2.2 Materials of construction

2.2.1 Where the construction requires post weld heat treatment, consideration should be given to certifying the material after subjecting the test pieces to a simulated heat treatment.

2.3 Tolerances for cylindrical shells

2.3.1 Measurements are to be made to the surface of the parent plate and not to a weld, fitting or other raised part.

2.3.2 In assessing the out-of-roundness of pressure vessels, the difference between the maximum and minimum internal diameters measured at one cross-section is not to exceed the amount given in Table 17.2.1.

Table 17.2.1 Tolerances for cylindrical shells

Nominal internal diameter of vessel in mm	Difference between maximum and minimum diameters	Maximum departure from designed form
≤ 300 > 300 ≤ 460 > 460 ≤ 600 > 600 ≤ 900 > 900 ≤ 1220 > 1220 ≤ 1520 > 1520 ≤ 1900	1,0 per cent of internal diameter	1,2 mm 1,6 mm 2,4 mm 3,2 mm 4,0 mm 4,8 mm 5,6 mm
> 1900 ≤ 2300 > 2300 ≤ 2670 > 2670 ≤ 3950	19 mm	6,4 mm 7,2 mm 8,0 mm
> 3950 ≤ 4650 > 4650	19 mm 0,4 per cent of internal diameter	0,2 per cent of internal diameter

2.3.3 The profile measured on the inside or outside of the shell, by means of a gauge of the designed form of the shell, and having a chord length equal to one quarter of the internal diameter of the vessel, is not to depart from the designed form by more than the amount given in Table 17.2.1. This amount corresponds to x in Fig. 17.2.1.

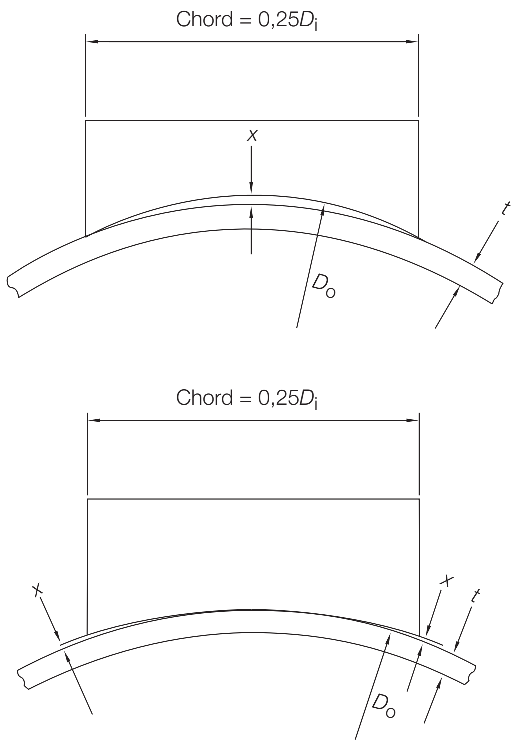


Fig. 17.2.1 Tolerances for cylindrical shells

2.3.4 Shell sections are to be measured for out-of roundness, either when laid flat on their sides or when set up on end. When the shell sections are checked while lying on their sides, each measurement for diameter is to be repeated after turning the shell through 90° about its longitudinal axis. The two measurements for each diameter are to be averaged, and the amount of out-of-roundness calculated from the average values so determined.

2.3.5 Where there is any local departure from circularity due to the presence of flats or peaks at welded seams, the departure from designed form shall not exceed that of Table 17.2.1.

2.3.6 The external circumference of the completed shell is not to depart from the calculated circumference (based upon nominal inside diameter and the actual plate thickness) by more than the amounts given in Table 17.2.2.

Table 17.2.2 Circumferential tolerances

Outside diameter (nominal inside diameter plus twice actual plate thickness), in mm	Circumferential tolerance
300 to 600 inclusive	±5 mm
Greater than 600	±0,25 per cent

■ *Section 3* Repairs to welds on fusion welded pressure vessels

3.1 General

3.1.1 Repairs to welds on fusion welded pressure vessels are to be in accordance with the requirements of Chapter 13 of the Rules for Materials.

■ *Section 4* Post-weld heat treatment of pressure vessels

4.1 General

4.1.1 Post-weld heat treatment of fusion welded pressure vessels are to be in accordance with the requirements of Chapter 13 of the Rules for Materials.

■ *Section 5* Welded pressure pipes

5.1 General

5.1.1 Fabrication of pipework is to be carried out in accordance with the requirements of Ch 13,5 of the Rules for Materials.

5.2 Welding workmanship

5.2.1 Preheating is to be effected by a method which ensures uniformity of temperature at the joint. The method of heating and the means adopted for temperature control are to be to the satisfaction of the Surveyors.

5.2.2 All welding is to be performed in accordance with the approved welding procedures in this Section by welders who are qualified for the materials, joint types and welding processes employed.

5.2.3 Welding without filler metal is generally not permitted for welding of duplex stainless steel materials.

5.2.4 All welds in high pressure and high temperature pipelines are to have a smooth surface finish and even contour; if necessary, they are to be made smooth by grinding.

5.2.5 Check tests of the quality of the welding are to be carried out periodically at the discretion of the Surveyors.

Section 6
Non-Destructive Examination

6.1 General

6.1.1 Non-Destructive Examination (NDE) of pressure vessels and piping is to be performed in accordance with the requirements of Ch 13,4 and 5 of the Rules for Materials.

■ *Section 1* General requirements

1.1 General

1.1.1 This Chapter is in addition to other relevant Chapters of the Rules.

1.1.2 The Rules contained in this Chapter cover machinery arrangements and control systems necessary for operating essential machinery from a (centralised) control station on the bridge under normal sea-going and manoeuvring conditions, but do not signify that the machinery space may be operated unattended.

1.1.3 In general, units complying with the requirements of this Chapter will be eligible for the machinery class notation **IP**, *see* Pt 1, Ch 2,2.5.

1.1.4 The details of control systems will vary with the type of machinery being controlled, and special consideration will be given to each case.

1.2 Plans

1.2.1 **Control systems**. Where control systems are applied to essential machinery or equipment, the following plans are to be submitted in triplicate:

- Details of operating medium, i.e., pneumatic, hydraulic or electric, including standby sources of power.
- Description of operation with explanatory diagrams.
- Line diagrams of control circuits.
- List of monitored points.
- List of control points.
- List of alarm points.
- Test schedule, including test facilities provided.

1.2.2 Plans for the control systems of the following machinery are to be submitted:

- Main propelling machinery, including all auxiliaries essential for propulsion.
- Controllable pitch propellers.
- Electric generating plant.
- Evaporating and distilling systems for use with main steam machinery.
- Steam-raising plant for essential services.

1.2.3 **Alarm systems**. Details of the overall alarm system linking the machinery space control station with the bridge control station are to be submitted.

1.2.4 **Control stations**. Details of bridge and machinery space control stations are to be submitted, e.g., control panels and consoles.

1.2.5 **Machinery configurations**. Plans showing the general arrangement of the machinery space, together with the layout and configuration of the main propulsion and essential machinery, are to be submitted.

■ *Section 2* Machinery arrangements

2.1 Main propulsion machinery

2.1.1 The main propulsion machinery may be oil engines, turbines or electric motors, but the configuration of the propulsion system and its relationship with other essential equipment is to comply with the remaining requirements of this Section.

2.1.2 The main propulsion machinery is to drive one of the generators, as required by 2.2.2. This generator is to be capable of supplying the essential electrical load under all normal sea-going and manoeuvring conditions.

2.1.3 Standby machinery is to be provided which is capable of being readily connected to the main propulsion system to provide emergency propulsion. This standby machinery is to be capable of connection in order to provide an alternative drive to the generator required in 2.1.2. It need not provide power to both systems simultaneously, *see also* 2.2.2.

2.2 Supply of electric power and essential services

2.2.1 Continuity of electrical power supply and essential services are to be ensured under all normal sea-going and manoeuvring conditions without manual intervention in the machinery space. Methods by which this may be achieved include automatic start-up of generating sets and essential pumps or manual start-up of these services from the bridge.

2.2.2 Generating sets and converting sets are to be sufficient to ensure the operation of services essential for the propulsion and safety of the unit, even when one generating set or converting set is out of service.

2.3 Controllable pitch propellers

2.3.1 For propulsion systems with controllable pitch propellers, a standby or alternative power source for the actuating medium for controlling the pitch of the propeller blades is to be provided.

■ *Section 3* Control arrangements

3.1 Bridge control

3.1.1 Means are to be provided to ensure satisfactory control of propulsion from the bridge in both the ahead and astern directions when operating on either the main or standby engine(s).

3.1.2 Instrumentation to indicate the following is to be fitted on the bridge and at any other station from which the propulsion machinery may be controlled:
(a) Propeller speed.
(b) Direction of rotation of the propeller for a fixed pitch propeller.
(c) Pitch position for a controllable pitch propeller.
(d) Direction and magnitude of thrust.
(e) Clutch position, where applicable.

3.1.3 An alarm is to operate in the event of a failure of the power supply to the bridge control system.

3.1.4 Means independent of the bridge control system are to be provided on the bridge to enable the watchkeeping officer to stop the main propulsion machinery in an emergency.

3.2 Alarm system

3.2.1 An alarm system is to be provided to indicate faults in essential machinery and control systems in accordance with this Chapter.

3.2.2 Machinery faults are to be indicated at the control stations on the bridge and in the machinery space.

3.2.3 In the event of a machinery fault occurring, the alarm system is to be such that the watchkeeping officer on the bridge is made aware of the following:
(a) A machinery fault has occurred.
(b) The machinery fault is being attended to, and
(c) The machinery fault has been rectified. (Alternative means of communication between the bridge control station and the machinery control station may be used for this function.)

3.2.4 The alarm system should be designed with self-monitoring properties. As far as practicable, any fault in the alarm system should cause it to fail to the alarm condition.

3.2.5 The alarm system should be capable of being tested during normal machinery operation.

3.2.6 Failure of the power supply to the alarm system is to be indicated as a separate fault alarm.

3.2.7 Alarm indication is to be both audible and visual. If arrangements are made to silence audible alarms, they are not to extinguish visual alarms.

3.2.8 The acceptance of an alarm on the bridge is not to silence the audible alarm in the machinery space.

3.2.9 Machinery alarms should be distinguishable from other audible alarms, e.g., fire, carbon dioxide.

3.2.10 Acknowledgement of visual alarms is to be clearly shown.

3.2.11 If the audible alarm has been silenced and a second fault occurs before the first has been rectified, the audible alarm is again to operate. To assist in the detection of transient faults which are subsequently self-correcting, fleeting alarms should lock in until accepted.

3.2.12 Arrangements should be made to enable alarm lights on the bridge to be dimmed as required.

3.3 Communication

3.3.1 Two means of communication are to be provided between the bridge and the control station in the machinery space. One of these means may be the bridge control system; the other is to be independent of the main electrical power supply.

3.3.2 The bridge, machinery space control station and any other control position from which the propulsion machinery can be controlled are to be fitted with means to indicate which station is in command.

3.3.3 Changeover between control stations is to be possible under all normal sea-going and manoeuvring conditions without affecting the speed or direction of propulsion. This changeover may be effected only with the acceptance of the station taking control.

3.4 Engine starting safeguards

3.4.1 Where it is possible to start a main propulsion or auxiliary oil engine from the bridge, an indication that sufficient starting air pressure is available is to be provided on the bridge.

3.4.2 The number of automatic consecutive attempts which fail to produce a start is to be limited to safeguard sufficient starting air pressure, or, in the case of electric starting, a sufficient charge level in the batteries.

3.4.3 An alarm is to be provided for low starting air pressure, set at a limit which will still permit engine starting operations.

3.4.4 Where propulsion or auxiliary engines are started from the bridge, interlocks are to be provided to prevent starting of the engine under conditions which could hazard the machinery. These are to include 'turning gear engaged', 'low lubricating oil pressure' and 'shaft brake engaged'.

3.5 Operational safeguards

3.5.1 Means are to be provided to prevent the machinery and shafting being subjected to excessive torque or other detrimental mechanical and thermal overloads.

3.5.2 Prolonged running in a restricted speed range is to be prevented automatically or, alternatively, an indication of restricted speed ranges is to be provided at each control station.

3.5.3 For units propelled by steam turbines, the risk of thermal distortion of the turbines is to be prevented by automatic steam spinning when the shaft is stopped in the manoeuvring mode. An audible and visual alarm is to operate on the bridge and in the machinery space when the shaft has been stopped for two minutes.

3.5.4 In the case of lubricating oil systems for main propulsion and standby engine(s), the engine(s) is to be stopped automatically on failure of the lubricating oil supply. The circuit and sensor employed for this automatic shut-down are to be additional to the alarm circuit and sensor required by Ch 14,8. Where means are provided to override the automatic shut-down required by this paragraph, the arrangements are to be such as to preclude inadvertent operation. Visual indication of operation of the override is to be fitted.

3.5.5 In the case of oil engines, oil mist monitoring is to be provided for crankcase protection where arrangements are fitted to override the automatic stop for failure of the lubricating oil supply.

3.5.6 Boilers with automatic controls, which under normal operating conditions, do not require any manual intervention by the operators, are to be provided with safety arrangements which automatically shut off the oil fuel to all the burners in the event of either low water level or combustion air failure. Oil fuel is to be shut off automatically to any burner in the event of flame failure.

3.5.7 Arrangements are to be provided to stop automatically propulsion gas turbines for the following fault conditions:
(a) Overspeed, *see* Ch 4,4;
(b) High exhaust temperature, *see* Ch 4,3;
(c) Flame failure; or
(d) Excessive vibration.

3.5.8 Where standby pumps are arranged to start automatically in the event of low discharge pressure from the working pump, an alarm is to be given to indicate when the standby pump has started.

3.6 Automatic control of essential services

3.6.1 All control systems for essential services are to be stable throughout the operating range of the main propulsion machinery.

3.6.2 The temperature of the following is to be automatically controlled within normal operating limits:
Oil engines:
(a) Lubricating oil to the main engine and/or auxiliary engines.
(b) Oil fuel – temperature or viscosity.
(c) Piston coolant, where applicable.
(d) Cylinder coolant to main and auxiliary engines, where applicable.
(e) Fuel valve coolant, where applicable.
Steam plant:
(a) Lubricating oil to main engine and/or auxiliary engines.
(b) Oil fuel to burners – temperature or viscosity.
(c) Superheated steam.
(d) External de-superheated steam.
Gas turbines:
(a) Lubricating oil to main engine and auxiliary engines.
(b) Oil fuel – temperature or viscosity.
(c) Exhaust gas.

3.6.3 The pressure of the following is to be automatically controlled within normal operating limits:
Steam plant:
(a) Superheated steam.
(b) Oil fuel.
(c) External de-superheated steam system(s).
(d) Gland steam.
(e) Reduced steam ranges.

3.6.4 The level of the following is to be automatically controlled within normal operating limits:
Steam plant:
(a) Boiler drum level.
(b) De-aerator level.
(c) Condenser level.

3.6.5 Boilers essential for the propulsion of the vessel are to be provided with an automatic combustion control system.

3.7 Local control

3.7.1 The arrangements are to be such, that essential machinery can be operated with the system of bridge control or any automatic controls out of action. Alternatively, the control systems should have sufficient redundancy so that failure of the control equipment in use does not render essential machinery inoperative.

Section

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter apply to the design and construction of steering gear applicable to units designed to undertake self-propelled passages without external assistance.

1.1.2 Whilst the requirements satisfy the relevant regulations of the *International Convention for the Safety of Life at Sea, 1974* as amended, and the IMO MODU Code, 2009, attention should be given to any relevant statutory requirements of the National Authority of the country in which the unit is to be registered.

1.1.3 Consideration will be given to other cases, or to arrangements which are equivalent to those required by the Rules.

1.1.4 When a ship type unit is classed as a floating offshore installation and the rudder is inoperative, reference should be made to Pt 4, Ch 10,1.

1.1.5 Where rudders are left *in situ* on ship type units, positive locking devices are to be fitted to steering gears to prevent rudders moving violently in storm conditions. Plans, together with supporting design calculations, are to be submitted for approval to show satisfactory capacity in the worst contemplated environmental conditions.

1.1.6 Consideration of the predicted extreme wind and wave loadings, unit orientation and wave headings, together with all other relevant environmental conditions at the site, are to be taken into account in predicting forces and moments on the rudder control systems.

1.1.7 In some circumstances, the positive locking devices required by 1.1.5 may be omitted if it can be shown that, during storm conditions, the existing (installed) hydraulic steering control system, either temporarily power-operated or left with passive trapped hydraulic fluid in the circuit but with relief valves open, is sufficient to counteract or dampen the imposed rudder moments such as to control violent movements of the rudder. However, in such cases, it may still prove necessary to carry out fatigue analysis of the rudder to tiller and support arrangements, taking into account the expected environmental sea wave velocity spectrums and structural natural frequencies to ensure satisfactory fatigue lives.

1.2 Definitions

1.2.1 **Steering gear control system** means the equipment by which orders are transmitted from the navigating bridge to the steering gear power units. Steering gear control systems comprise transmitters, receivers, hydraulic control pumps and their associated motors, motor controllers, piping and cables.

1.2.2 **Main steering gear** means the machinery, rudder actuator(s), the steering gear power units, if any, and ancillary equipment and the means of applying torque to the rudder stock (e.g., tiller or quadrant) necessary for effecting movement of the rudder for the purpose of steering the unit under normal service conditions.

1.2.3 **Steering gear power unit** means:

(a) in the case of electric steering gear, an electric motor and its associated electrical equipment;

(b) in the case of electrohydraulic steering gear, an electric motor and its associated electrical equipment and connected pump;

(c) in the case of other hydraulic steering gear, a driving engine and connected pump.

1.2.4 **Auxiliary steering gear** means the equipment other than any part of the main steering gear necessary to steer the unit in the event of failure of the main steering gear but not including the tiller, quadrant or components serving the same purpose.

1.2.5 **Power actuating system** means the hydraulic equipment provided for supplying power to turn the rudder stock, comprising a steering gear power unit or units, together with the associated pipes and fittings, and a rudder actuator. The power actuating systems may share common mechanical components, i.e., tiller quadrant and rudder stock, or components serving the same purpose.

1.2.6 **Maximum ahead service speed** means the maximum service speed which the unit is designed to maintain, at the summer load waterline at maximum propeller RPM and corresponding engine MCR.

1.2.7 **Rudder actuator** means the components which convert directly hydraulic pressure into mechanical action to move the rudder.

1.2.8 **Maximum working pressure** means the maximum expected pressure in the system when the steering gear is operated to comply with 2.1.2(b).

1.3 General

1.3.1 The steering gear is to be secured to the seating by fitted bolts, and suitable chocking arrangements are to be provided. The seating is to be of substantial construction.

1.3.2 The steering gear compartment is to be:

(a) readily accessible and, as far as practicable, separated from machinery spaces; and

(b) Provided with suitable arrangements to ensure working access to steering gear machinery and controls. These arrangements are to include handrails and gratings or other non-slip surfaces to ensure suitable working conditions in the event of hydraulic fluid leakage.

1.4 Plans

1.4.1 Before starting construction, the steering gear machinery plans, specifications and calculations are to be submitted. The plans are to give:

(a) Details of scantlings and materials of all load bearing and torque transmitting components and hydraulic pressure-retaining parts together with proposed rated torque and all relief valve settings.

(b) Schematic of the hydraulic system(s), together with pipe material, relief valves and working pressures.

(c) Details of control and electrical aspects.

1.5 Materials

1.5.1 All the steering gear components and the rudder stock are to be of sound reliable construction to the Surveyor's satisfaction.

1.5.2 All components transmitting mechanical forces to the rudder stock are to be tested according to the requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

1.5.3 Ram cylinders, pressure housings of rotary vane type actuators, hydraulic power piping, valves, flanges and fittings, and all steering gear components transmitting mechanical forces to the rudder stock (such as tillers, quadrants, or similar components) are to be of steel or other approved ductile material, duly tested in accordance with the requirements of the Rules for Materials. In general, such material is to have an elongation of not less than 12 per cent and a tensile strength not in excess of 650 N/mm^2. Special consideration will be given to the acceptance of grey cast iron for valve bodies and redundant parts with low stress levels.

1.5.4 Where appropriate, consideration will be given to the acceptance of non-ferrous material.

1.6 Rudder, rudder stock, tiller and quadrant

1.6.1 For the requirements of rudder and rudder stock, *see* Pt 3, Ch 13,2 of the Rules for Ships.

1.6.2 For the requirements of tillers and quadrants including the tiller to stock connection, *see* Table 19.1.1.

1.6.3 In bow rudders having a vertical locking pin operated from the deck above, positive means are to be provided to ensure that the pin can be lowered only when the rudder is exactly central. In addition, an indicator is to be fitted at the deck to show when the rudder is exactly central.

1.6.4 The factor of safety against slippage, S (i.e., for torque transmission by friction) is generally based on:

$$S = \frac{\text{the torque transmissible by friction}}{M}$$

where

M is the maximum torque at the relief valve pressure which is generally equal to the design torque as specified by the steering gear manufacturer.

1.6.5 For conical sections, S is based on the following equation:

$$S = \frac{\mu A \sigma_r}{\sqrt{(W + A \sigma_r \theta)^2 + Q^2}}$$

where

A = interfacial surface area, in mm^2

W = weight of rudder and stock, if applicable, when tending to separate the fit, in N

Q = shear force = $\dfrac{2M}{d_m}$ in N

where

d_m is the mean contact diameter of tiller/stock interface and M in Nmm is defined in 1.6.4, in mm

θ = cone taper half angle in radians (e.g., for cone taper 1:10, θ = 0,05)

μ = coefficient of friction

σ_r = radial interfacial pressure or grip stress, in N/mm^2.

Table 19.1.1 Connection of tiller to stock

Item	Requirements
(1) Dry fit – tiller to stock, *see also* 1.6.4 and 1.6.5	(a) For keyed connection, factor of safety against slippage, S = 1,0 The maximum stress in the fillet radius of the tiller keyway should not exceed the yield stress For conical sections, the cone taper should be ≤ 1:10 (b) For keyless connection, factor of safety against slippage, S = 2,0 The maximum equivalent von Mises stress should not exceed the yield stress For conical sections, the cone taper should be ≤ 1:15 (c) Coefficient of friction (maximum) = 0,17 (d) Grip stress not to be less than 20 N/mm^2
(2) Hydraulic fit – tiller to stock, *see also* 1.6.4 and 1.6.5	(a) For keyed connection, factor of safety against slippage, S = 1,0 The maximum stress in the fillet radius of the tiller keyway should not exceed the yield stress For conical sections, the cone taper should be ≤ 1:10 (b) For keyless connection, factor of safety against slippage, S = 2,0 The maximum equivalent von Mises stress should not exceed the yield stress For conical sections, the cone taper should be ≤ 1:15 (c) Coefficient of friction (maximum) = 0,14 (d) Grip stress not to be less than 20 N/mm^2
(3) Ring locking assemblies fit – tiller to stock, *see also* 1.6.3	(a) Factor of safety against slippage, S = 2,0 The maximum equivalent von Mises stress should not exceed the yield stress (b) Coefficient of friction = 0,12 (c) Grip stress not to be less than 20 N/mm^2
(4) Bolted tiller and quadrant (this arrangement could be accepted provided the proposed rudder stock diameter in way of tiller does not exceed 350 mm diameter), *see* symbols	Shim to be fitted between two halves before machining to take rudder stock, then removed prior to fitting Minimum thickness of shim, For 4 connecting bolts: $t_s = 0{,}0014\ \delta_t$ mm For 6 connecting bolts: $t_s = 0{,}0012\ \delta_t$ mm Key(s) to be fitted Diameter of bolts, $\delta_{tb} = \dfrac{0{,}60\ \delta_{su}}{\sqrt{n_{tb}}}$ mm A predetermined setting-up load equivalent to a stress of approximately 0,7 of the yield strength of the bolt material should be applied to each bolt on assembly. A lower stress may be accepted provided that two keys, complying with item (5), are fitted Distance from centre of stock to centre of bolts should generally be equal to $\delta_t \left(1{,}0 + \dfrac{0{,}30}{\sqrt{n_{tb}}}\right)$ mm Thickness of flange on each half of the bolted tiller ≥ $\dfrac{0{,}66\ \delta_t}{\sqrt{n_{tb}}}$ mm
(5) Key/keyway, *see* symbols	Effective sectional area of key in shear ≥ $0{,}25\ \delta_t^2$ mm^2 Key thickness ≥ $0{,}17\ \delta_t$ mm Keyway is to extend over full depth of tiller and is to have a rounded end. Keyway root fillets are to be provided with suitable radii to avoid high local stress
(6) Section modulus – tiller arm (at any point within its length about vertical axis), *see* symbols	To be not less than the greater of: (a) $Z_{TA} = \dfrac{0{,}15\ \delta_t^3\ (b_T - b_s)}{1000\ b_T}$ cm^3 (b) $Z_{TA} = \dfrac{0{,}06\ \delta_t^3\ (b_T - 0{,}9\ \delta_t)}{1000\ b_T}$ cm^3 If more than one arm fitted, combined modulus is to be not less than the greater of (a) or (b) For solid tillers, the breadth to depth ratio is not to exceed 2
(7) Boss, *see* symbols	Depth of boss ≥ δ_t Thickness of boss in way of tiller ≥ $0{,}4\ \delta_t$

Symbols

b_s = distance between the section of the tiller arm under consideration and the centre of the rudder stock, in mm
NOTE: b_T and b_s are to be measured with zero rudder angle

b_T = distance from the point of application of the load on the tiller to the centre of the rudder stock, in mm

n_{tb} = number of bolts in the connection flanges, but generally not to be taken greater than six

t_s = thickness of shim for machining bolted tillers and quadrants, in mm

Z_{TA} = section modulus of tiller arm, in cm^3

δ_t = Rule rudderstock diameter in way of tiller, *see* Pt 3, Ch 13 of the Rules for Ships

δ_{tb} = diameter of bolts securing bolted tillers and quadrants, in mm

Section 2 Performance

2.1 General

2.1.1 Unless the main steering gear comprises two or more identical power units, in accordance with 2.1.4 or 8.1.1, every unit is to be provided with a main steering gear and an auxiliary steering gear, in accordance with the requirements of the Rules. The main steering gear and the auxiliary steering gear are to be so arranged that the failure of one of them will not render the other one inoperative.

2.1.2 The main steering gear and rudder stock is to be:

(a) Of adequate strength and capable of steering the unit at maximum ahead service speed, which shall be demonstrated in accordance with 7.2;

(b) Capable of putting the rudder over from 35° on one side to 35° on the other side with the unit at its deepest sea-going draught and running ahead at maximum ahead service speed and under the same conditions, from 35° on either side to 30° on the other side in not more than 28 seconds;

(c) Operated by power where necessary to meet the requirements of (b) and in any case when the Rules, excluding strengthening for navigation in ice, require a rudder stock over 120 mm diameter in way of the tiller; and

(d) So designed that they will not be damaged at maximum astern speed; however, this design requirement need not be proved by trials at maximum astern speed and maximum rudder angle.

2.1.3 The auxiliary steering gear is to be:

(a) Of adequate strength and capable of steering the unit at navigable speed and of being brought speedily into action in an emergency;

(b) Capable of putting the rudder over from 15° on one side to 15° on the other side in not more than 60 seconds with the unit at its deepest sea-going draught and running ahead at one half of the maximum ahead service speed or 7 knots, whichever is the greater; and

(c) Operated by power where necessary to meet the requirements of (b) and in any case when the Rules, excluding strengthening for navigation in ice, require a rudder stock over 230 mm diameter in way of the tiller.

2.1.4 Where the main steering gear comprises two or more identical power units, an auxiliary steering gear need not be fitted, provided that the main steering gear is arranged so that, after a single failure in its piping system or in one of the power units, the defect can be isolated so that steering capability can be maintained or speedily regained.

2.1.5 Main and auxiliary steering gear power units are to be:

(a) Arranged to restart automatically when power is restored after power failure;

(b) Capable of being brought into operation from a position on the navigating bridge. In the event of a power failure to any one of the steering gear power units, an audible and visual alarm is to be given on the navigating bridge;

(c) Arranged so that transfer between units can be readily effected.

2.1.6 Where the steering gear is so arranged that more than one power or control system can be simultaneously operated, the risk of hydraulic locking caused by a single failure is to be considered.

2.1.7 A means of communication is to be provided between the navigating bridge and the steering gear compartment.

2.1.8 Steering gear, other than of the hydraulic type, will be accepted provided the standards are considered equivalent to the requirements of this Section.

2.2 Rudder angle limiters

2.2.1 Power-operated steering gears are to be provided with positive arrangements, such as limit switches, for stopping the gear before the rudder stops are reached. These arrangements are to be synchronised with the gear only and not with the steering gear control.

Section 3 Construction and design

3.1 General

3.1.1 Rudder actuators other than those covered by 8.3 and the 'Guidelines' are to be designed in accordance with the relevant requirements of Chapter 11 for Class I pressure vessels (notwithstanding any exemptions for hydraulic cylinders).

3.1.2 Accumulators, if fitted, are to comply with the relevant requirements of Chapter 11.

3.1.3 The welding details and welding procedures are to be approved. All welded joints within the pressure boundary of a rudder actuator or connecting parts transmitting mechanical loads are to be of full penetration type or of equivalent strength.

3.1.4 The construction is to be such as to minimise local concentrations of stress.

3.1.5 The design pressure for calculations to determine the scantlings of piping and other steering gear components subjected to internal hydraulic pressure shall be at least 1,25 times the maximum working pressure, which is to be expected under the operational conditions specified in 2.1.2(b), taking into account any pressure which may exist in the low pressure side of the system. Fatigue criteria may be applied for the design of piping and components, taking into account pulsating pressures due to dynamic loads, *see* Section 9.

3.1.6 For the rudder actuator, the permissible primary general membrane stress is not to exceed the lower of the following values:

$$\frac{\sigma_B}{A} \text{ or } \frac{\sigma_y}{B}$$

where

σ_B = specified minimum tensile strength of material at ambient temperature

σ_y = specified minimum yield stress or 0,2 per cent proof stress of the material at ambient temperature

A and *B* are given by the following Table:

	Wrought steel	*Cast steel*	*Nodular cast iron*
A	3,5	4	5
B	1,7	2	3

3.2 Components

3.2.1 Special consideration is to be given to the suitability of any essential component which is not duplicated. Any such essential component shall, where appropriate, utilise anti-friction bearings such as ball bearings, roller bearings or sleeve bearings which shall be permanently lubricated or provided with lubrication fittings.

3.2.2 All steering gear components transmitting mechanical forces to the rudder stock, which are not protected against overload by structural rudder stops or mechanical buffers, are to have a strength of at least the equivalent to that of the rudder stock in way of the tiller.

3.2.3 Actuator oil seals between non-moving parts, forming part of the external pressure boundary, are to be of the metal type or of an equivalent type.

3.2.4 Actuator oil seals between moving parts, forming part of the external pressure boundary, are to be duplicated, so that the failure of one seal does not render the actuator inoperative. Alternative arrangements providing equivalent protection against leakage may be accepted.

3.2.5 Piping, joints, valves, flanges and other fittings are to comply within the requirements of Chapter 12 for Class I piping systems components. The design pressure is to be in accordance with 3.1.5.

3.2.6 Hydraulic power-operated steering gears are to be provided with the following:

(a) Arrangements to maintain the cleanliness of the hydraulic fluid, taking into consideration the type and design of the hydraulic system;

(b) A fixed storage tank having sufficient capacity to recharge at least one power actuating system including the reservoir, where the main steering gear is required to be power-operated. The storage tank is to be permanently connected by piping, in such a manner that the hydraulic systems can be readily recharged from a position within the steering gear compartment and provided with a contents gauge.

3.3 Valve and relief valve arrangements

3.3.1 For vessels with non-duplicated actuators, isolating valves are to be fitted at the connection of pipes to the actuator, and are to be directly fitted on the actuator.

3.3.2 Arrangements for bleeding air from the hydraulic system are to be provided, where necessary.

3.3.3 Relief valves are to be fitted to any part of the hydraulic system which can be isolated and where pressure can be generated from the power source or from external forces. The settings of the relief valves is not to exceed the design pressure. The valves are to be of adequate size and so arranged as to avoid an undue rise in pressure above the design pressure.

3.3.4 Relief valves for protecting any part of the hydraulic system which can be isolated, as required by 3.3.3, are to comply with the following:

(a) The setting pressure is not to be less than 1,25 times the maximum working pressure.

(b) the minimum discharge capacity of the relief valve(s) is not to be less than 110 per cent of the total capacity of the pumps which can be delivered through them. Under such conditions, the rise in pressure is not to exceed 10 per cent of the setting pressure. In this regard, due consideration is to be given to extreme foreseen ambient conditions, in respect of oil viscosity.

3.4 Flexible hoses

3.4.1 Hose assemblies approved by LR may be installed between two points where flexibility is required but are not to be subjected to torsional deflection (twisting) under normal operating conditions. In general, the hose should be limited to the length necessary to provide for flexibility and for proper operation of machinery, *see also* Ch 12,7.

3.4.2 Hoses should be high pressure hydraulic hoses, according to recognised standards and should be suitable for the fluids, pressures, temperatures and ambient conditions in question.

3.4.3 Burst pressure of hoses is to be not less than four times the design pressure.

Section 4
Steering control systems

4.1 General

4.1.1 Steering gear control is to be provided:

(a) For the main steering gear, both on the navigating bridge and in the steering gear compartment;

(b) Where the main steering gear is arranged according to 2.1.4, by two independent control systems, both operable from the navigating bridge. This does not require duplication of the steering wheel or steering lever. Where the control system consists of a hydraulic telemotor, a second independent system does not need to be fitted, except in a oil storage unit of 10000 gross tonnage and upwards;

(c) For the auxiliary steering gear, in the steering gear compartment and, if power-operated, it shall also be operable from the navigating bridge and is to be independent of the control system for the main steering gear; and

(d) Where the steering gear is so arranged that more than one control system can be simultaneously operated, the risk of hydraulic locking caused by single failure is to be considered.

4.1.2 Any main and auxiliary steering gear control system, operable from the navigating bridge, is to comply with the following:

(a) Means are to be provided in the steering gear compartment for disconnecting any control system operable from the navigating bridge from the steering gear it serves;

(b) The system is to be capable of being brought into operation from a position on the navigating bridge.

4.1.3 The angular position of the rudder shall:

(a) Be indicated on the navigating bridge, if the main steering gear is power-operated. The rudder angle indication is to be independent of the steering gear control system;

(b) Be recognisable in the steering gear compartment.

4.1.4 Appropriate operating instructions with a block diagram showing the changeover procedures for steering gear control systems and steering gear actuating systems, which are to be permanently displayed in the wheelhouse and in the steering gear compartment.

4.1.5 Where the system failure alarms for hydraulic lock, *see* Table 19.5.1, are provided, appropriate instructions shall be placed on the navigating bridge to shut down the system at fault.

Section 5
Electric power circuits, electric control circuits, monitoring and alarms

5.1 Electric power circuits

5.1.1 Short-circuit protection, an overload alarm and, in the case of polyphase circuits, an alarm to indicate single phasing is to be provided for each main and auxiliary motor circuit. Protective devices are to operate at not less than twice the full load current of the motor or be circuit protected. They are to allow excess current to pass during the normal accelerating period of the motors.

5.1.2 The alarms required by 5.1.1 are to be provided on the bridge and in the main machinery space or control room from where the main machinery is normally controlled.

5.1.3 Indicators for running indication of each main and auxiliary motor are to be installed on the navigating bridge and at a suitable main machinery control position.

5.1.4 A low-level alarm is to be provided for each power actuating system and hydraulic fluid reservoir to give the earliest practicable indication of hydraulic fluid leakage. Alarms are to be given on the navigation bridge and in the machinery space where they can be readily observed.

5.1.5 Two exclusive circuits are to be provided for each electric or electrohydraulic steering gear arrangement, consisting of one or more electric motors.

5.1.6 Each of these circuits is to be fed from the main switchboard. One of these circuits may pass through the emergency switchboard.

5.1.7 One of these circuits may be connected to the motor of an associated auxiliary electric or electrohydraulic power unit.

5.1.8 Each of these circuits is to have adequate capacity to supply all the motors which can be connected to it and that can operate simultaneously.

5.1.9 These circuits are to be permanently separated and as widely as is practicable.

5.1.10 In units of less than 1600 gross tonnage, if an auxiliary steering gear is not electrically powered or is powered by an electric motor primarily intended for other services, the main steering gear may be fed by one circuit from the main switchboard. Consideration would be given to other protective arrangements other than what is described in 5.1.1, for such a motor which is primarily intended for other services.

5.2 Electric control circuits

5.2.1 Electric control systems are to be independent and separated as far as is practicable throughout their length.

5.2.2 Each main and auxiliary electric control system which is to be operated from the navigating bridge is to comply with the following:

(a) It is to be served with electric power by a separate circuit supplied from the associated steering gear power circuit, from a point within the steering gear compartment, or directly from the same section of switchboard busbars, main or emergency, to which the associated steering gear power circuit is connected.

(b) Each separate circuit is to be provided with short-circuit protection only.

5.3 Monitoring and alarms

5.3.1 Alarms and monitoring requirements are indicated in 5.3.2 and Table 19.5.1.

Table 19.5.1 Alarm requirements

Item	Alarm	Note
Rudder position	— Failure	Indication, *see* 4.1.3 *See* 5.3.3
Steering gear power units, power	Failure	—
Steering gear motors	Overload Single phase	For alarm and running indication locations, *see* 5.1.2 and 5.1.3
Control system	Failure	*See* 5.3.3
Control system power	Failure	—
Steering gear hydraulic oil level	Low	Each reservoir to be monitored. For alarm locations, *see* 5.1.4
Auto pilot	Failure	Running indication
Hydraulic oil temperature	High	Where oil cooler is fitted
Hydraulic lock	Fault	Where more than one system (either power or control) can be operated simultaneously each system is to be monitored, *see* Note
Hydraulic oil filter differential pressure	High	When oil filters are fitted

NOTE
This alarm is to identify the system at fault and to be activated when (for example):
- position of the variable displacement pump control system does not correspond with given order; or
- incorrect position of 3-way full flow valve or similar in constant delivery pump system is detected.

5.3.2 The alarms described in Table 19.5.1 are to be indicated on the navigating bridge and additional locations are to be described in accordance with the alarm system, as specified by Pt 6, Ch 1,2.3.

5.3.3 Steering control systems are to be monitored and an audible and visual alarm is to be initiated on the navigation bridge in the event of:

- failure of the control system, including command and feedback circuits; or
- unacceptable deviation between the rudder order and actual rudder position and/or unacceptable delay in response to changes in the rudder order.

■ *Section 6*
Emergency power

6.1 General

6.1.1 Where the rudder stock is required to be over 230 mm diameter in way of the tiller, excluding strengthening for navigation in ice, an alternative power supply, sufficient at least to supply the steering gear power unit, which complies with the requirements of 2.1.3 and also its associated control system and the rudder angle indicator, shall be provided automatically, within 45 seconds, either from the emergency source of electrical power or from an independent source of power located in the steering gear compartment. This independent source of power should only be used for this purpose.

6.1.2 In every unit of 10 000 gross tonnage and upwards, the alternative power supply shall have a capacity for at least 30 minutes of continuous operation and in any other unit for at least 10 minutes.

6.1.3 Where the alternative power source is a generator, or an engine driven pump, starting arrangements are to comply with the requirements relating to the starting arrangements of emergency generators.

■ *Section 7*
Testing and trials

7.1 Testing

7.1.1 The requirements of the Rules relating to the testing of Class 1 pressure vessels, piping, and related fittings, including hydraulic testing apply.

7.1.2 After installation on board the unit, the steering gear is to be subjected to the required hydrostatic and running tests.

7.1.3 Each type of power unit pump is to be subjected to a type test. The type test shall be for a duration of not less than 100 hours and the test arrangements are to be such that the pump may run in idling conditions, and at maximum delivery capacity at maximum working pressure. During the test, idling periods are to be alternated with periods at maximum delivery capacity at maximum working pressure. The passage from one condition to another should occur at least as quickly as on board. During the whole test, no abnormal heating, excessive vibration or other irregularities are permitted. After the test, the pump is to be opened out and inspected. Type tests may be waived for a power unit which has been proven to be reliable in marine service.

7.2 Trials

7.2.1 The steering gear is to be tried out on the trial trip in order to demonstrate to the Surveyor's satisfaction that the requirements of the Rules have been met. The trial is to include the operation of the following:

(a) The steering gear, including demonstration of the performances required by 2.1.2(b) and 2.1.3(b):
- For the main steering gear trial, the propeller pitch of controllable pitch propellers is to be at the maximum design pitch approved for the maximum continuous ahead RPM;
- If the unit cannot be tested at the deepest draught, alternative trial conditions may be specially considered. In this case, for the main steering gear trial, the speed of the ship unit corresponding to the maximum continuous revolutions of the main engine should apply:

(b) The steering gear power units, including transfer between steering gear power units;
(c) The isolation of one power actuating system, checking the time for regaining steering capability;
(d) The hydraulic fluid recharging system;
(e) The emergency power supply required by 6.1.1;
(f) The steering gear controls, including transfer of control and local control;
(g) The means of communication between the steering gear compartment and the wheelhouse, also the engine room, if applicable;
(h) The alarms and indicators;
(j) Where the steering gear is designed to avoid hydraulic locking, this feature shall be demonstrated.

Test items (d), (g), (h) and (j) may be effected at the dockside.

■ *Section 8* Additional requirements

8.1 For oil storage units of 10 000 tons gross and upwards and every other unit of 70 000 tons gross and upwards

8.1.1 The main steering gear is to comprise of two or more identical power units, complying with provisions of 2.1.4.

8.2 For oil storage units of 10 000 tons gross and upwards

8.2.1 Subject to 8.3, the following are to be complied with:

(a) The main steering gear is to be so arranged that in the event of loss of steering capability due to a single failure in any part of one of the power actuating systems of the main steering gear, excluding the tiller, quadrant or components serving the same purpose, or seizure of the rudder actuators, steering capability is to be regained in no more than 45 seconds after the loss of one power actuating system.

(b) The main steering gear is to comprise of either:
  (i) two independent and separate power actuating systems, each capable of meeting the requirements of 2.1.2(b); or
  (ii) at least two identical power actuating systems which, acting simultaneously in normal operation, are capable of meeting the requirements of 2.1.2(b). Where necessary to comply with these requirements, inter-connection of hydraulic power actuating systems is to be provided. Loss of hydraulic fluid from one system is to be capable of being detected and the defective system is automatically isolated so that the other actuating system or systems remain fully operational.

(c) Steering gears other than the hydraulic type are to achieve equivalent Standards.

8.3 For oil storage units of 10 000 tons gross and upwards but of less than 100 000 tons deadweight

8.3.1 Solutions other than those set out in 8.2.1, which need not apply the single failure criterion to the rudder actuator or actuators, may be permitted provided that an equivalent safety Standard is achieved and that:

(a) Following loss of steering capability due to a single failure of any part of the piping system or in one of the power units, steering capability is regained within 45 seconds; and

(b) Where the steering gear includes only a single rudder actuator, special consideration is given to stress analysis for the design, including fatigue analysis and fracture mechanics analysis, as appropriate, the material used, the installation of sealing arrangements and the testing and inspection and provision of effective maintenance. In consideration of the foregoing arrangements, regard will be given to the 'Guidelines' in Section 9.

8.3.2 Manufacturers of the steering gear who intend their product to comply with the requirements of the 'Guidelines', are to submit full details when plans are forwarded for approval.

Section 9
'Guidelines' for the acceptance of non-duplicated rudder actuators for oil storage units of 10 000 tons gross and upwards but of less than 100 000 tons deadweight

9.1 Materials

9.1.1 Parts subject to internal hydraulic pressure or transmitting mechanical forces to the rudder stock are to be made of duly tested ductile materials complying with recognised Standards. Materials for pressure retaining components are to be in accordance with recognised pressure vessel Standards. These materials are not to have an elongation less than 12 per cent, nor a tensile strength in excess of 650 N/mm^2.

9.2 Design

9.2.1 **Design pressure**. The design pressure should be assumed to be at least equal to the greater of the following:

(a) 1,25 times the maximum working pressure to be expected under the operating conditions required in 2.1.2(b).

(b) The relief valve(s) setting.

9.2.2 **Analysis**. In order to analyse the design, the following are required:

(a) The manufacturers of rudder actuators should submit detailed calculations showing the suitability of the design for the intended service.

(b) A detailed stress analysis of pressure retaining parts of the actuator should be carried out to determine the stresses at the design pressure.

(c) Where considered necessary because of the design complexity or manufacturing procedures, a fatigue analysis and fracture mechanics analysis may be required. In connection with these analyses, all fore-seen dynamic loads should be taken into account. Experimental stress analysis may be required in addition to, or in lieu of, theoretical calculations depending upon the complexity of the design.

9.2.3 **Dynamic loads for fatigue and fracture mechanics analysis**. The assumption for dynamic loading for fatigue and fracture mechanics analysis where required by 3.1.5, 8.3 and 9.2.2 are to be submitted for appraisal. Both the case of high cycle and cumulative fatigue are to be considered.

9.2.4 **Allowable stresses**. For the purposes of determining the general scantlings of parts of rudder actuators subject to internal hydraulic pressure, the allowable stresses should not exceed:

$$\sigma_m \le f$$
$$\sigma_1 \le 1{,}5f$$
$$\sigma_b \le 1{,}5f$$
$$\sigma_1 + \sigma_b \le 1{,}5f$$
$$\sigma_m + \sigma_b \le 1{,}5f$$

where

f = the lesser of $\frac{\sigma_B}{A}$ or $\frac{\sigma_y}{B}$

σ_b = equivalent primary bending stress

σ_m = equivalent primary general membrane stress

σ_y = specified minimum yield stress or 0,2 per cent proof stress of material at ambient temperature

σ_B = specified minimum tensile strength of material at ambient temperature

σ_1 = equivalent primary local membrane stress

A and *B* are as follows:

	Wrought steel	*Cast steel*	*Nodular cast iron*
A	4	4,6	5,8
B	2	2,3	3,5

9.2.5 **Burst test**. Pressure retaining parts not requiring fatigue analysis and fracture mechanics analysis may be accepted on the basis of a certified burst test and the detailed stress analysis required by 9.2.2 need not be provided.
The minimum bursting pressure should be calculated as follows:

$$P_b = P A \frac{\sigma_{Ba}}{\sigma_B}$$

where

A = as from Table in 9.2.4

P = design pressure, as defined in 9.2.1

P_b = minimum bursting pressure

σ_B = tensile strength, as defined in 9.2.4

σ_{Ba} = actual tensile strength.

9.3 Construction details

9.3.1 **General**. The construction should be such as to minimise local concentrations of stress.

9.3.2 **Welds**.

(a) The welding details and welding procedures should be approved.

(b) All welded joints within the pressure boundary of a rudder actuator or connection parts transmitting mechanical loads should be a full penetration type or of equivalent strength.

9.3.3 **Oil seals**. Oil seals forming part of the external pressure boundary are to comply with 3.2.3 and 3.2.4.

9.3.4 **Isolating valves** are to be fitted at the connection of pipes to the actuator, and should be directly mounted on the actuator.

9.3.5 **Relief valves** for protecting the rudder actuator against over-pressure as required in 3.3.3 are to comply with the following:

(a) The setting pressure is not to be less than 1,25 times the maximum working pressure expected under operating conditions required by 2.1.2(b).

(b) The minimum discharge capacity of the relief valve(s) is to be not less than 110 per cent of the total capacity of all pumps which provided power for the actuator. Under such conditions, the rise in pressure should not exceed 10 per cent of the setting pressure. In this regard, due consideration should be given to extreme foreseen ambient conditions in respect of oil viscosity.

9.4 Non-destructive testing

9.4.1 The rudder actuator should be subjected to suitable and complete non-destructive testing to detect both surface flaws and volumetric flaws. The procedure and acceptance criteria for non-destructive testing should be in accordance with requirements of recognised Standards. If found necessary, fracture mechanics analysis may be used for determining maximum allowable flaw size.

9.5 Testing

9.5.1 Tests, including hydrostatic tests, of all pressure parts at 1,5 times the design pressure should be carried out, subject to any limitations imposed by valves and other components. Where additional testing of systems or subsystems following final assembly is required, the test pressure may be subject to any limitations imposed by valves and other components.

9.5.2 When installed on board the unit, the rudder actuator should be subjected to a hydrostatic test at the pressure, defined in 9.5.1, as well as a running test.

9.6 Additional requirements for steering gear fitted to units with Ice Class notations

9.6.1 *See* Pt 3, Ch 6.

■ *Section 1* General requirements

1.1 Application

1.1.1 This Chapter applies to azimuth or rotatable thruster units for propulsion or D.P. duty which transmit a power greater than 220 kW used as the sole means of steering and are in addition to the relevant requirements of Chapter 19.

1.1.2 In general, for a unit to be assigned an unrestricted service notation, a minimum of two azimuth thruster units are to be provided where these form the sole means of propulsion. Where a single thruster installation is proposed, it will be subject to special consideration.

1.2 Plans

1.2.1 The following additional plans are to be submitted for consideration, together with particulars of materials and the maximum shaft power and revolutions per minute:

- Sectional assembly, including nozzle ring structure, nozzle support struts, etc.
- Shafts, gears and couplings.
- Steering mechanisms with details of ratings.
- Bearing specifications.
- Schematic piping systems.

■ *Section 2* Performance

2.1 General

2.1.1 The arrangement of thrusters is to be such that the unit can be satisfactorily manoeuvred.

2.1.2 In addition to the requirements of Chapter 19, the azimuthing mechanism is to be capable of a maximum rotational speed of not less than 1,5 rev/min.

■ *Section 3* Construction and design

3.1 Materials

3.1.1 Specification for materials of gears, shafts, couplings and propeller, giving chemical composition, heat treatment and mechanical properties, are to be submitted for approval.

3.1.2 Specification for materials for the stock, struts, etc., are to be submitted for approval.

3.1.3 Where an ice class notation is included in the class of a unit, additional requirements are applicable, as detailed in Part 8 of the Rules for Ships and Pt 3, Ch 6.

3.2 Design

3.2.1 The requirements detailed in Chapters 1, 5, 6, 7, 8, 9, 14 and 19 are to be complied with where applicable.

3.2.2 For steerable thrusters with a nozzle, the equivalent rudder stock diameter in way of tiller, used in Table 19.1.1 in Chapter 19, is to be determined as follows:

$$\delta_t = 26{,}03 \sqrt[3]{(V + 3)^2 A_N x_P} \quad \text{mm}$$

where

V = maximum service speed, in knots, which the unit is designed to maintain under thruster operation

A_N = projected nozzle area, in m^2, and is equal to the length of the nozzle multiplied by the mean external vertical height of the nozzle

and

x_P = horizontal distance from the centreline of the steering tube to the centre of pressure, in metres. The position of the centre of pressure is determined for both ahead and astern cases from Pt 3, Ch 13,2.2.1of the Rules for Ships.

The corresponding maximum turning moment, M_T, is to be determined as follows:

M_T = turning moment for conical couplings and is to be taken as the greatest of M_F, M_A or M_W

M_F = $P_L\, x_P \times 10^6$ N mm (kgf mm) in the ahead condition

M_A = $P_L\, x_P \times 10^6$ N mm (kgf mm) in the astern condition

M_W = the torque generated by the steering gear at the maximum working pressure supplied by the manufacturer, in N mm (kgf mm). M_W is not to exceed the greater of $3{,}0M_F$ or $3{,}0M_A$

P_L = lateral force on rudder acting at the centre of pressure, as defined in Pt 3, Ch 13,2.1.1 of the Rules for Ships (where A_R equals $2A_N$), in kN (tonne-f).

3.2.3 The nozzle structure is to be in accordance with Pt 3, Ch 13,3 of the Rules for Ships.

3.2.4 In addition to the requirements of Table 13.3.1, in Pt 3, Ch 13 of the Rules for Ships, the scantlings of the nozzle stock or steering tube are to be such that the section modulus against transverse bending at any section xx is not less than:

$$Z = 1{,}73 \sqrt{(V + 3)^4 A_N^2 x_P^2 + \frac{a^2}{4} T_M^2 10^4} \quad \text{cm}^3$$

where

a = dimension, in metres, as shown in Fig. 20.3.1

T_M = maximum thrust of the thruster unit in tonnes.

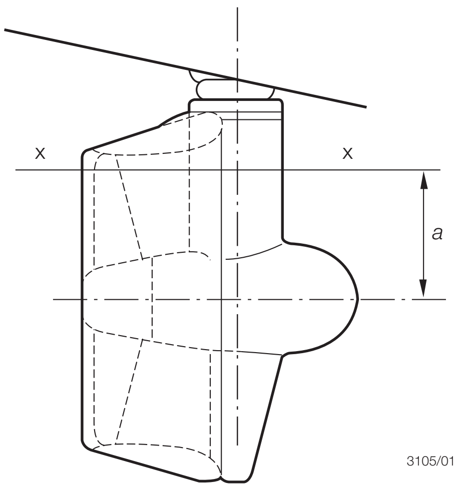


Fig. 20.3.1 Steerable thruster

3.2.5 The scantlings of nozzle connections or struts will be specially considered. In the case of certain high powered units, direct calculation may be required.

3.2.6 For steerable thrusters without a nozzle the scantlings in way of the tiller will be specially considered.

3.3 Steering gear elements

3.3.1 These gears are to be considered for the following conditions:

- a design maximum dynamic duty steering torque;
- a static duty (≤10^3 load cycles) steering torque, and the static duty steering torque should be not less than M_T.

Values for the above should be submitted together with the plans.

3.4 Components

3.4.1 The hydraulic power operating systems for each azimuth thruster are to be provided with the following:

(a) arrangements to maintain the cleanliness of the hydraulic fluid, taking into consideration the type and design of the hydraulic system;

(b) a fixed storage tank having sufficient capacity to recharge at least one azimuth power actuating system, including the reservoir. The piping from the storage tank is to be permanent and arranged in such a manner as to allow recharging from within the thruster space.

■ *Section 4* Control engineering arrangements

4.1 General

4.1.1 Except where indicated in this Section, the control engineering systems are to be in accordance with Pt 6, Ch 1.

4.1.2 Steering control is to be provided for the azimuth thrusters from the navigating bridge, the main machinery control station and locally.

4.1.3 An indication of the angular position of the thruster(s) and the magnitude of the thrust are to be provided at each station from which it is possible to control the direction of thrust.

4.1.4 Means are to be provided at the remote control station(s) to stop each thrust unit.

4.1.5 Where machinery is arranged to start automatically or from a remote control position, interlocks are to be provided to prevent start-up under conditions which could hazard the machinery.

4.1.6 Means are to be provided to prevent leaks from high pressure hydraulic control equipment piping, dripping or spraying on to hot surfaces or into machinery air inlets.

4.1.7 For controllable pitch propellers for main propulsion, a standby or alternative power source of actuating medium for controlling the pitch of propeller blades is to be provided. Automatic start of the standby pump supplying hydraulic power for pitch control is provided.

4.2 Monitoring and alarms

4.2.1 Alarms and monitoring requirements are indicated in 4.2.2 and Table 20.4.1.

4.2.2 The alarms described in Table 20.4.1 are to be indicated individually on the navigating bridge and in accordance with the alarm system specified by Pt 6, Ch 1,2.3.

4.2.3 For controllable pitch propellers for main propulsion, a shaft speed indicator and a pitch indicator which shows the degree of pitch as a measure of the propeller blade or actuator movement are to be provided at each station from which it is possible to control shaft speed or propeller pitch.

Table 20.4.1 Alarms for control systems

Item	Alarm	Note
Thruster azimuth	–	Indicator, *see* 4.1.3
Steering motor	Power failure, single phase	Also running indication on bridge and at machinery control station
Propulsion motor	Overload, power failure	Also running indication on bridge and at machinery control station
Control system power	Failure	
Hydraulic oil supply tank level	Low	
Hydraulic oil system pressure	Low	
Hydraulic oil system temperature	High	Where oil cooler is fitted
Hydraulic oil filters differential pressure	High	Where oil filters are fitted
Lubricating oil supply	Low	If separate forced lubrication

Section 5
Electrical equipment

5.1 General

5.1.1 The electrical installation is to be designed, constructed and installed in accordance with the requirements of 5.2 to 5.4.

5.1.2 Where the thruster units are electrically driven, the relevant requirements including surveys, of Pt 6, Ch 2 are to be complied with.

5.2 Generating arrangements

5.2.1 Where a central power generation system is employed, the requirements of Pt 6, Ch 2,16.3.5 of the Rules for Ships are to be complied with.

5.2.2 The generating and distribution system is to be so arranged that after any single failure, steering capability can be maintained or regained within a period not exceeding 45 seconds, and the effectiveness of the steering after such a fault will not be reduced by more than 50 per cent. This may be achieved by the parallel operation of two or more generating sets, or alternatively, when the electrical requirements are met by one generating set in operation, on loss of power, this may be achieved by the automatic starting and connection to the switchboard of a standby set, provided that this set can restart and run a thruster with its auxiliaries.

5.2.3 The failure of one thruster unit or its control system is not to render any other thruster inoperative.

5.3 Distribution arrangements

5.3.1 Thruster auxiliaries and controls are to be served by individual circuits. Services that are duplicated are to be separated throughout their length as widely as is practicable and without the use of common feeders, transformers, converters, protective devices or control circuits.

5.4 Auxiliary supplies

5.4.1 Where the auxiliary services and thruster units are supplied from a common source, the following requirements are to be complied with:

(a) the voltage regulation and current sharing requirements defined in Pt 6, Ch 2,9.4.2 and 9.4.7 of the Rules for Ships are to be maintained over the full range of power factors that may occur in service;

(b) auxiliary equipment and services are to operate with any waveform distortion introduced by converters without deleterious effect. This may be achieved by the provision of suitably filtered/converted supplies.

Section 6
Testing and trials

6.1 General

6.1.1 The requirements detailed in Chapters 1, 5 and 19 are to be complied with and, in addition, the performance specified in 2.1.2 is to be demonstrated to the Surveyor's satisfaction.

6.1.2 The actual values of steering torque should be verified during sea trials to confirm that the design maximum dynamic duty torque has not been exceeded.

■ *Section 1* Requirements for Condition Monitoring Systems

1.1 Scope

1.1.1 The requirements of this Chapter are applicable to condition monitoring systems which:

(a) provide control, alarm or safety functions for essential machinery and equipment, *see* Pt 6, Ch 1,2.1.1, in accordance with manufacturers' recommendations; or

(b) provide machinery condition related information as part of a machinery planned maintenance scheme for use as an alternative to machinery and equipment surveys required by the Regulations, *see* Pt 1, Ch 3, in accordance with LR's ShipRight procedures.

1.1.2 Condition monitoring systems which deviate from the requirements of this Section but provide an equivalent level of performance may be submitted to LR for consideration.

1.1.3 The requirements of this Section are to be applied to condition monitoring systems where the assignment of the **MCM** descriptive note is requested.

1.2 Plans and particulars

1.2.1 The information and plans required to be submitted are specified in the relevant Chapters of Parts 5 and 6 applicable to the particular machinery and where specified in this Chapter.

1.2.2 In addition to information required by 1.2.1, the documents listed in the *ShipRight Procedures for Machinery Planned Maintenance and Condition Monitoring* are to be submitted to LR for consideration.

1.2.3 Equipment type approval reports providing evidence of compliance with 1.3.1 and 1.3.2 are to be submitted.

1.2.4 Additional information and plans providing evidence of compliance with the requirements of 1.3.3, 1.4.1 and 1.5.3 are to be submitted.

1.3 General requirements for condition monitoring systems

1.3.1 Condition monitoring equipment is to be capable of providing the service for which it is intended and is to satisfy the relevant requirements for condition monitoring equipment in LR's *Type Approval System, Product Assessment and Test Specification (TACM)*.

1.3.2 Condition monitoring equipment is to be suitable for the environment in which it is intended to operate and is to satisfy the relevant requirements for environmental testing in LR's *Type Approval System, Test specification No.1*.

1.3.3 The installation of condition monitoring equipment in spaces and locations in which flammable mixtures are liable to collect, e.g., areas containing flammable gas or vapour and/or combustible dust, is to be minimised as far as is practicable and is to satisfy the relevant requirements for the use of electrical equipment in flammable atmospheres in Pt 6, Ch 2,14 of the Rules for Ships.

1.3.4 Where permanently installed condition monitoring systems are used, the cables are to comply with the relevant Sections of Pt 6, Ch 2,11 and the piping systems are to comply with the relevant Sections of Chapters 12 and 13.

1.3.5 Where the system is based on programmable electronic systems, the requirements of Pt 6, Ch 1,2.9 are to be complied with.

1.4 Requirements for systems providing control, alarm and safety functions

1.4.1 In addition to the requirements of 1.3, condition monitoring equipment which provides control, alarm or safety functions for essential machinery and equipment is also to satisfy the relevant requirements for control, alarm and safety systems in Pt 6, Ch 1 and the installation of electrical equipment in Pt 6, Ch 2.

1.5 Requirements for systems providing machinery condition-related information as part of machinery planned maintenance scheme

1.5.1 In addition to the requirements of 1.3, condition monitoring equipment which provides machinery condition-related information as part of a machinery planned maintenance scheme for use as an alternative to machinery and equipment surveys required by the Regulations is also to satisfy the relevant requirements of LR's *ShipRight Procedures for Machinery Planned Maintenance and Condition Monitoring*.

1.5.2 The condition monitoring equipment is, as far as is practicable, to be located and installed such that it is accessible for maintenance and survey.

1.5.3 The condition monitoring equipment is to be installed in accordance with the manufacturer's instructions, *see* the *Product Assessment and Test Specification (TACM),* or by an approved technical organisation as defined in the *ShipRight Procedures for Machinery Planned Maintenance and Condition Monitoring*, and to the satisfaction of the LR Surveyor.

■ *Section 1* General requirements

1.1 General

1.1.1 This Chapter states the requirements for units having machinery redundancy, and are in addition to the relevant requirements in other relevant Sections of these Rules.

1.1.2 The requirements, which are optional, cover machinery arrangements and control systems necessary for units which have propulsion and steering systems configured such that, in the event of a single failure of a system or item of active equipment, *see* 1.1.3, the unit will retain the ability to use available installed prime mover capacity and installed propulsion systems that are unaffected by the failure. The unit is also to retain steering capability at a service speed of not less than seven knots. The requirements also cover machinery arrangements where the propulsion and steering systems are installed in separate compartments such that, in the event of a loss of one compartment, the unit will retain availability of propulsion power and manoeuvring capability.

1.1.3 For the purposes of this Chapter, items of active equipment are those which have a defined function for operation of a propulsion or steering system, such as, but not limited to:

- Prime movers, i.e., diesel engines, electric motors, steam turbines and gas turbines;
- Generators and their excitation equipment;
- Transformers and converters;
- Gearing and shafting systems;
- Propulsion devices, i.e., propellers, water jets and thrusters;
- Pumps;
- Valves (where power actuated);
- Fuel treatment plant;
- Coolers/heaters;
- Filters.

Piping and electrical cables connecting items of active equipment are not considered to be active.

1.1.4 Requirements additional to these Rules may be imposed by the Flag State with whom the unit is registered and/or by the Administration within whose territorial jurisdiction the unit is intended to operate.

1.1.5 Sections 2, 3 and 4 state the applicable requirements for arrangements necessary to maintain availability of propulsion and manoeuvring capability, in the event of a single failure in equipment. Units complying with the applicable requirements of Sections 2 to 4 will be eligible for the machinery class notation **PMR** or **PMRL** (Propulsion Machinery Redundancy), **SMR** or **SMRL** (Steering Machinery Redundancy) or **PSMR** or **PSMRL** (Propulsion and Steering Machinery Redundancy), which will be recorded on the ClassDirect Live website.

NOTE

The additional **L** character to **PMR**, **SMR** and **PSMR** notations indicates a limited capability.

1.1.6 Section 5 states the additional requirements necessary to maintain availability of propulsion and manoeuvring capability where machinery is installed in separate compartments and the loss of any one compartment due to fire or flooding has been addressed. Units complying with the applicable requirements of Sections 2 to 5 of this Chapter will be eligible for the machinery class notation **PMR★** or **PMRL★** (Propulsion Machinery Redundancy in separate machinery spaces), **SMR★** or **SMRL★** (Steering Machinery Redundancy in separate machinery spaces) or **PSMR★** or **PSMRL★** (Propulsion and Steering Machinery Redundancy in separate machinery spaces) which will be recorded on the ClassDirect Live website.

1.1.7 For assignment of **PSMR** or **PSMR★** machinery class notations, the unit is to retain the ability to use not less than 50 per cent of the installed prime mover capacity and not less than 50 per cent of the installed propulsion systems and retain steering capability at a service speed of not less than seven knots, in the event of a single failure of a system or item of equipment.

1.1.8 Where the unit does not comply with 1.1.7 but can retain a service speed of not less than seven knots using available installed prime mover capacity and propulsion systems (which may be less than 50 per cent) following a failure of a system or item of equipment, machinery class notations **PSMRL** or **PSMRL★** may be assigned. The available installed prime mover capacity and installed propulsion systems are to be identified and included in 1.2.7.

1.2 Plans and information

1.2.1 In addition to the plans and information required by Parts 5 and 6, the information detailed in 1.2.2 to 1.2.6 is also to be submitted.

1.2.2 **Machinery spaces**. Plans showing the general arrangement of the machinery spaces, together with a description of the propulsion system, main and emergency electrical power supply systems and steering arrangements, are to be submitted. The plans are to indicate segregation and access arrangements for machinery spaces and associated control rooms/stations.

1.2.3 **Failure Mode and Effects Analysis (FMEA)**. For the propulsion systems, electrical power supplies, essential services, control systems and steering arrangements, an FMEA report is to be submitted and is to address the requirements identified in Sections 2 and 5.

1.2.4 **Manoeuvring capability**. An assessment of the unit's ahead and astern manoeuvring capability, under the following operating conditions, is to be submitted:

(a) Where only 50 per cent or less of the installed prime mover capacity and 50 per cent or less of the installed propulsion systems are available.

(b) Where the steering capability requirements described in 3.2.1 are available.

IMO Resolution MSC 137(76) – *Standards for Ship Manoeuvrability*, provides guidance on standard manoeuvres required in an assessment of the manoeuvrability of units.

1.2.5 **Testing and trials procedures**. A schedule of testing and trials to demonstrate that the unit is capable of being operated with machinery functioning as described in 4.2 is to be submitted. In addition, any testing programme that may be necessary to prove the conclusions of the FMEA is to be submitted.

1.2.6 **Operating Manuals**. Operating Manuals are to be submitted for information and provided on board. The manuals are to include the following information:

(a) Particulars of machinery and control systems.

(b) General description of systems for propulsion and steering.

(c) Operating instructions for all machinery and control systems used for propulsion and steering.

(d) Procedures for dealing with the situations identified in the FMEA report.

1.2.7 **Installed prime mover capacity and installed propulsion systems**. A schedule of the propulsion systems and their operating capacity and capability under normal and foreseeable failure conditions is to be submitted.

■ *Section 2*
Failure Mode and Effects Analysis (FMEA)

2.1 General

2.1.1 An FMEA is to be carried out in accordance with 2.1.2 to 2.1.7 for the propulsion systems, electrical power supply systems and steering systems to demonstrate that a single failure in active equipment or loss of an associated sub-system, *see* 1.1.3, will not cause loss of all propulsion and/or steering capability as required by a class notation. Typical sub-systems include associated control and monitoring arrangements, data communications, power supplies (electrical, hydraulic or pneumatic), fuel, lubricating, cooling, etc.

2.1.2 The FMEA is to be carried out using the format presented in Table 22.2.1 or an equivalent format that addresses the same safety issues. Analyses in accordance with IEC 60812, *Analysis techniques for system reliability – Procedure for Failure Mode and Effects Analysis (FMEA)* or IMO MSC Resolution 36(63) Annex 4 – *Procedures for Failure Mode and Effects Analysis* would be acceptable.

2.1.3 The FMEA is to be organised in terms of equipment and function. The effects of item failures at a stated level and at higher levels are to be analysed to determine the effects on the system as a whole. Actions for mitigation are to be determined.

2.1.4 The FMEA is to:

(a) identify the equipment or sub-system, mode of operation and the equipment;

(b) identify potential failure modes and their causes;

(c) evaluate the effects on the system of each failure mode;

(d) identify measures for reducing the risks associated with each failure mode; and

(e) identify trials and testing necessary to prove conclusions.

Table 22.2.1 Failure Mode and Effects Analysis

<table>
<tr><td colspan="12">Project:
Failure Mode and Effects Analysis</td></tr>
<tr><td colspan="4">System:</td><td colspan="7">Element:</td><td>Sheet No:</td></tr>
<tr><td rowspan="2">Item No.</td><td rowspan="2">Component Description</td><td rowspan="2">Function</td><td rowspan="2">Mode of Operation</td><td rowspan="2">Failure Mode</td><td rowspan="2">Failure Cause</td><td rowspan="2">Failure Detection</td><td colspan="2">Effect of Failure</td><td rowspan="2">Severity</td><td rowspan="2">Corrective Action</td><td rowspan="2">Remarks</td></tr>
<tr><td>On Item</td><td>On System</td></tr>
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<tr><td colspan="12">NOTE
The 'severity category' is to be in accordance with the following:
(a) Catastrophic; (b) Hazardous; (c) Major; or (d) Minor.</td></tr>
</table>

2.1.5 At sub-system level, it is acceptable, for the purposes of these Rules, to consider failure of equipment items and their functions, e.g., failure of a pump to produce flow or pressure head. It is not required that the failure of components within that pump be analysed. In addition, their failure need only be dealt with as a cause of failure of the pump.

2.1.6 Where FMEA is used for consideration of systems that depend on software-based functions for control or co-ordination, the analysis is to investigate failure of the functions rather than a specific analysis of the software code itself.

2.1.7 The FMEA is to establish that, in the event of a single failure:

(a) for **PSMR** and **PSMR★** notations, that the unit will retain not less than 50 per cent of the installed prime mover capacity and not less than 50 per cent of the installed propulsion systems and retain steering capability;

(b) for **PMR** and **PMR★** notations, that the unit will retain not less than 50 per cent of the installed prime mover capacity and not less than 50 per cent of the installed propulsion systems;

(c) for **SMR** and **SMR★** notations, that the steering capability remains available;

(d) for **PSMRL★** notation, that the unit will retain the ability to use available installed prime mover capacity and installed propulsion systems that are not directly affected by the failure and retain steering capability at a service speed of not less than seven knots; and

(e) for **PMRL★** notation, that the unit will retain the ability to use available installed prime mover capacity and installed propulsion systems that are not directly affected by the failure.

■ *Section 3* Machinery arrangements

3.1 Main propulsion machinery

3.1.1 For **PSMR**, **PSMR★**, **PMR** and **PMR★** notations, independent main propulsion systems are to be provided so that the unit will retain not less than 50 per cent of the prime mover capacity and not less than 50 per cent of the installed propulsion systems in the event of a single failure of a system or active item of equipment, *see* 1.1.3. In the event of a single failure of an item of equipment, the remaining system(s) is to be capable of maintaining a service speed of not less than seven knots and, for **PSMR** and **PSMR★** notations, give adequate manoeuvring capability, *see* 1.2.4.

3.1.2 For **PMRL**, **PSMRL**, **PMRL★** and **PSMRL★** notations, independent main propulsion systems are to be provided so that there remains the ability to use the remaining available installed prime mover capacity and installed propulsion systems following a single failure of a system or item of equipment. In the event of a single failure in equipment, the remaining system(s) is to be capable of maintaining a manoeuvring speed and, for **PSMRL** and **PSMRL★** notations, give adequate manoeuvring capability, *see* 1.2.4.

3.2 Steering machinery

3.2.1 For **PSMR**, **PSMR★**, **SMR** and **SMR★** notations, independent steering systems for manoeuvring the unit are to be installed, such that steering capability will continue to be available in the event of any of the following:

(a) Single failure in the steering gear equipment.

(b) Loss of power supply or control system to any steering system.

3.3 Electrical power supply

3.3.1 The main busbars of the switchboard supplying the propulsion machinery and essential services are to be capable of being isolated by a multi-pole linked circuit breaker, disconnector, or switch-disconnector into at least two independent sections.

3.3.2 In the event of the loss of one section or failure of the power supply from one generator, there is to be continuity of sufficient electrical power to supply essential services such that the available installed prime mover capacity and installed propulsion systems will continue to have the ability to function at their operational capability where **PSMRL**, **PSMRL★**, **PMRL** and **PMRL★** notations are required. *See* 3.2.1 for steering machinery requirements.

3.3.3 In the event of the loss of one section or failure of the power supply from one generator, there is to be continuity of sufficient electrical power to supply essential services such that the unit will retain not less than 50 per cent of the prime mover capacity and not less than 50 per cent of the installed propulsion systems where **PSMR**, **PSMR★**, **PMR** and **PMR★** notations are required. *See* 3.2.1 for steering machinery requirements.

3.3.4 For units capable of operating with one service generator connected to the switchboard, arrangements are to be such that a standby generator will automatically start and connect to the switchboard on the loss of the service generator. Sequential starting of essential services is to be provided.

3.3.5 For units operating with two or more generator sets in service connected to the switchboard, arrangements are to be such that, in the event of the loss of one generator, the remaining set(s) is to be adequate for the continuity of essential services supplied from that switchboard. This may be achieved by preferential tripping of non-essential services. Alternatively, arrangements can be such that a standby generator will start automatically and connect to the switchboard upon the loss of one of the generator sets in service.

3.4 Essential services for machinery

3.4.1 Services essential for the operation of the propulsion machinery, steering and the supply of electrical power are to be arranged so that the unit will retain not less than 50 per cent of the prime mover capacity and not less than 50 per cent of the installed propulsion systems, and retain steering capability in the event of a single failure in any of the services, where required by the respective class notations.

3.5 Oil fuel storage and transfer systems

3.5.1 The arrangements for the storage of oil fuel bunkers are to ensure that there is an adequate supply of existing oil fuel on board to allow sufficient time for a shore-based quality analysis of new bunkers, in accordance with ISO 8217 *Petroleum Products – Fuels (Class F) Specification of Marine Fuels,* prior to use.

3.5.2 Provision is to be made to enable samples of oil fuel to be taken at the bunkering manifolds.

■ *Section 4* Control arrangements

4.1 General

4.1.1 This Section states the requirements for the installation of control, alarm and safety systems but this does not signify that machinery spaces may be operated unattended. For unattended machinery space operation, compliance with Pt 6, Ch 1,4 is also required.

4.1.2 The control, alarm and safety systems required in 4.2 are to comply with Pt 6, Ch 1,2.

4.2 Bridge control

4.2.1 The controls, alarms, instrumentation and safeguards required in 4.2.2 to 4.2.6 are to be provided on the bridge.

4.2.2 For **PSMR**, **PSMR★**, **PMR** and **PMR★** notations, means are to be provided to ensure satisfactory control of propulsion in both the ahead and astern directions when all main propulsion systems are functioning and when one propulsion system is not available.

4.2.3 For **PSMR**, **PSMR★**, **SMR** and **SMR★** notations, means are to be provided to ensure satisfactory control of steering when all steering systems are functioning and when any one of the steering systems is not available.

4.2.4 Where required by 5.4.3, isolation of essential services is to be carried out, either automatically or manually from the bridge. Indication of the status of isolation arrangements is to be provided.

4.2.5 Instrumentation to indicate the operational status of running and standby machinery is to be provided for the propulsion systems, the supply of electrical power, steering systems and other essential services.

4.2.6 Alarms are to be provided in the event of:
(a) A fire in any machinery compartment.
(b) A high bilge level in any machinery compartment. Irrespective of the assignment of the **UMS** notation, the bilge level detection system and arrangements for automatically pumping bilges, if applicable, are to comply with Pt 6, Ch 1,4.6.

■ *Section 5* Separate machinery spaces ★ (star) enhancement

5.1 General

5.1.1 This Section states the additional requirements where propulsion and steering machinery are installed in separate compartments such that, in the event of the loss of one compartment, the unit will retain availability of propulsion power and manoeuvring capability.

5.1.2 The machinery arrangements, control arrangements and FMEA required by Sections 2 to 4, together with testing and trials requirements in Section 6, are to be complied with, in addition to 5.2 to 5.7.

5.2 Machinery arrangements

5.2.1 The main propulsion machinery is to be arranged in no fewer than two compartments such that, in the event of the loss of one compartment, propulsion power and/or manoeuvring capability will continue to be available, where required by the respective class notations.

5.2.2 The steering systems are to be arranged in no fewer than two separate compartments, such that steering capability will continue to be available in the event of the loss of one compartment, where required by the respective class notations.

5.3 Electrical power supply

5.3.1 The generating sets and converting sets required by Pt 6, Ch 2,2 are to be arranged so that they are located in at least two separate machinery compartments.

5.3.2 The independent sections of the switchboard required by 3.3.1 are to be arranged in no fewer than two separate compartments.

5.3.3 In the event of the loss of one compartment, there is to be continuity of sufficient electrical power to supply essential services, such that propulsion power and steering capability will continue to be available.

5.4 Essential services for machinery

5.4.1 Services essential for the operation of the propulsion machinery, steering and the supply of electrical power are to be arranged so that propulsion power and steering capability are maintained in the event of the loss of one machinery compartment.

5.4.2 The design of systems which may have a common source, such as those used for supplying oil fuel, lubricating oil, fresh and sea-water cooling, ventilation of compartments and engine starting energy, is to ensure continuous availability of supply in the event of the loss of any one compartment. Where applicable, continuous availability of heating services, oil fuel and water treatments is also to be provided. *See* 3.5 and 5.6 for oil fuel storage and transfer systems.

5.4.3 Where essential services are arranged so that they may supply machinery in another compartment, means of isolation from that compartment is to be provided.

5.4.4 Where pumps for essential services are arranged to supply more than one compartment, standby pumps for the same supplies are to be provided in a different compartment. The standby pumps are to be arranged to start automatically if the discharge pressure from the working pumps falls below a predetermined value.

5.5 Bilge drainage arrangements

5.5.1 The independent power pumps for bilge drainage are to be located in two separate watertight compartments. Each pump is to be capable of draining any compartment. Means of isolation from other compartments is to be provided.

5.5.2 In addition to the independent power pumps installed to comply with 5.5.1, an emergency bilge drainage arrangement is to be provided in each main propulsion machinery space.

5.5.3 Each separate machinery compartment is to be provided with at least one independent power pump direct bilge suction.

5.6 Oil fuel storage

5.6.1 The oil fuel service tanks required by Ch 14,4.18 are to be located in separate compartments.

5.6.2 Provision is to be made to ensure that oil fuel preparation and transfer arrangements to the oil fuel service tanks are continuously available in the event of the loss of any one compartment, *see also* 5.4.2.

5.7 FMEA

5.7.1 The FMEA required by 2.1.1 for the propulsion systems, electrical power supplies, essential services, control systems and steering arrangements is also to address the following:

(a) Fire in a machinery space or control room.
(b) Flooding of any watertight compartment which could affect propulsion or steering capability.
(c) Separation of machinery spaces.

Section 6
Testing and trials

6.1 Sea trials

6.1.1 In addition to the requirements for sea trials in Ch 1,5.2, trials are to be carried out to demonstrate that when the unit is operating at 50 per cent of the prime mover capacity and 50 per cent of the installed propulsion systems, a speed of not less than 7 knots can be maintained with adequate steering capability, where required by the respective class notations.

6.1.2 Trials are to be carried out to demonstrate the unit's steering capability, in accordance with the assessment required by 1.2.4, with one steering system out of action.

6.1.3 Where the FMEA report has identified the need to prove the conclusions, testing and trials are to be carried out as necessary to investigate the following:

(a) The effect of a specific component failure.
(b) The effectiveness of automatic/manual isolation systems.
(c) The behaviour of any interlocks that may inhibit operation of essential systems.

6.1.4 During sea trials, the operational envelope(s) is to be determined under the conditions detailed in 3.1.1 and/or 3.2.1, as required for the class notation.

Section

Section 1 General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to self-elevating units with machinery of the rack and pinion type used to raise and lower the position of the hull with respect to the legs, or other supporting structure above the surface of the sea.

1.1.2 Machinery for self-elevating units utilising other systems will be specially considered.

1.2 Definitions

1.2.1 The following definitions are applicable to this Chapter:

(a) **Normal jacking load**. The maximum design elevated weight of the hull, including variable load, to be raised/ lowered by the jacking unit, during normal jacking operation.

(b) **Pre-load jacking load**. The maximum design elevated weight of the hull, including pre-load ballast load, to be lowered by the jacking unit in the event of sudden leg penetration during pre-load operation.

(c) **Pre-load holding load**. The maximum design elevated weight of the hull, including pre-load ballast, to be held by the jacking unit during the pre-load operation.

(d) **Ultimate holding load**. The maximum load capable of being held by the jacking unit, in an emergency situation, without causing slippage of the jacking gear machinery braking device.

(e) **Storm survival load**. The maximum static design load in the leg to be supported by the jacking and/or fixation systems.

(f) **Fixation system**. The mechanical locking device, with an engaging mechanism, used to provide positive engagement between the hull support structure and the leg chord.

(g) **Jacking gear unit**. The individual reduction gear assembly, comprising drive motor, coupling, enclosed reduction gearing and main pinion normally attached to the jack-house.

(h) **Jack-house**. The structure surrounding the leg chord into which multiple jacking units are installed.

1.3 Submission of plans and particulars

1.3.1 The following plans, together with the necessary particulars of the jacking mechanism are to be submitted for consideration:

- General arrangement of the self-elevating machinery, including a cross-sectional arrangement.
- Full design details of all transmission gear elements including gear tooth geometry and machining details.
- Full design details of all transmission shafting, couplings, coupling bolts, interference assemblies, keys, keyways.
- Bearing details.
- Enclosed gear casing details and mounting arrangements.
- All assembly design tolerances are to be submitted, including, where applicable, allowances for wear during normal operation such as rack guides.
- Prime mover specifications including braking devices.
- Drawing of main pinion and rack tooth profile showing full geometric details.
- Full design details of the fixation system, where fitted.
- A load-time spectrum for the envisaged dynamic operational requirements of the self-elevating machinery for the unit is to be specified.
- A simulated load analysis for the main pinion/rack tooth mesh during wet/dry tow conditions.

1.4 Material specifications

1.4.1 Specifications for materials for the gearing and other mechanical components giving chemical composition, heat treatment and mechanical properties are to be submitted for approval with the plans required by 1.3.1.

1.4.2 Where the teeth of a pinion or gear wheel are to be surface-hardened (i.e., carburised, nitrided, tufftrided or induction-hardened) the proposed specification and details of the procedure are to be submitted for approval.

Section 2 Materials

2.1 Material properties

2.1.1 Materials used for the construction of the jacking gear machinery are to comply with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials), or a National Standard acceptable to LR. *See* Ch 1,2.2 of the Rules for Materials for additional requirements for materials.

2.2 Non-destructive tests

2.2.1 An ultrasonic examination is to be carried out on all gear blanks where the finished diameter of the surfaces, where teeth will be cut, is in excess of 200 mm.

2.2.2 Magnetic particle or liquid penetrant examination is to be carried out on all surface-hardened teeth. This examination may also be requested on the finished machined teeth of through-hardened gears.

■ *Section 3* Design

3.1 General

3.1.1 Self-elevating systems are to be designed with redundancy such that a single failure of any component will not cause an uncontrolled descent of the unit or impair the safety of the unit. Each leg is to be provided with a load indication and an overload alarm at a manned control station.

3.1.2 Braking devices are to fail safe in the engaged position in the event of a failure or interruption of the power supply to the lifting machinery.

3.1.3 Unless otherwise agreed by LR, the system is to be designed such that the rack tooth is the weakest component in the self-elevating machinery with regard to static mechanical strength.

3.1.4 The jacking system, together with the fixation system if fitted, is to be capable of adequately lifting and supporting the hull, or leg installation under all operating, survival and tow conditions.

3.1.5 The self-elevating mechanism is to be designed to pre-load the foundation to the design conditions and be capable of supporting a load not less than the maximum load for which the leg has been designed.

3.1.6 The requirement for emergency jacking of the hull with full or part pre-load to stabilise the unit in the event of sudden leg penetration is to be considered.

3.1.7 In selecting the prime movers for the self-elevating machinery, consideration is to be given to the effects of friction at the mesh of the pinion and rack, and between legs and guides, together with uneven load distribution.

3.1.8 Unless otherwise agreed, the minimum design operating temperature of the jacking gear machinery is to be in accordance with Pt 3, Ch 1,4.4.

3.1.9 The control station from which the elevating and lowering machinery is operated is to be provided with all necessary monitoring, alarms and controls including hull alignment, prime mover running load pin position, running indication, overload alarms and indication of availability of applicable power sources, as appropriate.

3.2 Enclosed gearing

3.2.1 All enclosed transmission gearing is to be designed in accordance with a National Standard acceptable to LR.

3.2.2 The design is to have sufficient load capacity to meet the minimum requirements of Tables 23.3.1 and 23.3.2 and 3.2.3 to 3.2.5.

Table 23.3.1 Tooth flank bending strength

Tooth root bending strength	Required factor of safety S_{Fmin}
Dynamic operation:	
Normal jacking of hull and legs	1,5
Pre-load jacking of hull (*see* Note 1)	1,5
Static operation:	
Normal holding load (without fixation system engaged) (*see* Note 2)	1,5
Pre-load holding	1,5
Symbols	
S_{Fmin} is defined as $\dfrac{\sigma_{FP}}{\sigma_F}$ σ_{FP} = allowable tooth root bending stress σ_F = calculated tooth root bending stress	
NOTES 1. Based on 50 hours operation. 2. It is considered that where a fixation system is properly engaged the loading applied to the jacking gears will be minimal.	

Table 23.3.2 Tooth flank Hertzian stress

Tooth flank Hertzian stress	Required factor of safety S_{Hmin}
Dynamic operation	1,0
Static operation	1,0
Symbols	
S_{Hmin} is defined as $\dfrac{\sigma_{FP}}{\sigma_F}$ σ_{FP} = allowable Hertzian bending stress σ_F = calculated Hertzian bending stress	

3.2.3 The following design values are to be used in the assessment of the gear design unless otherwise agreed:

- Application factor, K_A:
  - Electric motor drive 1,0
- Load Sharing Factor $K\gamma$:
  - With pinion load monitoring 1,0
  - Without pinion load monitoring 1,2.

3.2.4 Material endurance strength limits are to comply with the requirements of a National Standard acceptable to LR.

3.2.5 Consideration is to be given to the loads applied to the gears during wet/dry tow conditions, as the gear teeth may be subjected to full load reversal. The design will be given consideration based on the simulated load analysis for the main pinion/rack tooth mesh.

3.3 Main pinion and rack

3.3.1 The design of the final (main) pinion and rack is subject to special consideration but the requirements of 3.3.2 to 3.3.7 are to be complied with.

3.3.2 The nominal contact ratio of the mesh is not to be less than 1,05, taking into consideration the cumulative effects of the design and assembly tolerance values and allowable wear during operation of the guides/rack tips.

3.3.3 The material hardness of the pinion is to be not less than that of the rack tooth material.

3.3.4 The pinion is to have a factor of safety on tooth root bending of not less than 1,5 for both static and dynamic loading conditions.

3.3.5 Hertzian tooth flank contact stress is generally not to be greater than three times the yield strength of the rack material, or not greater than 3,5 times the yield for pre-load jacking.

3.3.6 The ultimate strength (collapse load) of the main pinion tooth is not to be less than 1,1 times that of the rack tooth.

3.3.7 Consideration is to be given to the loads being applied to the main pinion mesh during wet/dry tow conditions where full load reversal may be expected.

3.4 Shafting

3.4.1 Nominal shaft stresses for the plain section solid shafting are to be calculated as follows:

$$\sigma_b = \frac{32\,000M}{\pi\, d_o^3}$$

$$\tau = \frac{16\,000T}{\pi\, d_o^3}$$

where

τ = calculated torsional shaft stress, in N/mm^2
T = shaft torque, in Nm
d_o = shaft outside diameter, in mm
σ_b = calculated bending shaft stress, in N/mm^2
M = bending moment, in Nm.

3.4.2 The maximum stresses due to bending and torsion are not to exceed the values shown in Fig. 23.3.1. The assessment of the maximum stresses should take into account the system overload conditions. The allowable stress limits in Fig. 23.3.1 include an allowance for stress concentrations at keyways, fillets shrink assemblies or other areas of stress concentration, not exceeding 3,0. Where an effective stress concentration exceeds this value, the design will be specially considered.

3.4.3 When designing a shaft for a finite number of rotating cycles, the allowable stresses may be increased by the factors in Table 23.3.3.

Table 23.3.3 Shaft stress multipliers

Cycles	Factor
Up to 1000 cycles	2,4
Over 1000 to 10 000 cycles	1,8
Over 10 000 to 100 000 cycles	1,4
Over 100 000 to 1 million cycles	1,1
1 million cycles and over	1,0

3.4.4 Shaft materials having properties outside the range covered by Fig. 23.3.1 will be specially considered.

3.5 Interference assemblies

3.5.1 A minimum factor of safety on slippage of 2,0 is to be achieved based on the maximum load.

3.6 Bearings

3.6.1 The capacity of the sleeve or anti-friction shaft bearings is to be such as to carry adequately the radial and thrust loads which would be induced under all operating conditions.

3.6.2 Hydrodynamic radial bearings are to be lined with babbitt or other material suitable for the intended application and duty. They are to be properly installed and secured in the housing against axial and rotational movement.

3.6.3 Selection of the particular design of sleeve bearing is to be based on an evaluation of the journal velocity, surface loading, hydrodynamic film thickness, and calculated bearing temperature under all operating conditions.

3.6.4 Selection of rolling element bearings is to be based upon the bearing manufacturer's recommendations for the design loading and application.

3.7 Braking device

3.7.1 Braking devices are to have a combined static friction torque capacity, considering the mechanical efficiency of the drive gear, such that no fewer than 1,3 times the maximum design load, to be supported during normal operation, may be held without brake slippage.

3.7.2 Means are to be provided such that, in the event of failure of one or more of the self-elevating machinery units, the defective unit(s) can be mechanically isolated such that the effectiveness of the remaining units in raising/lowering the hull is not impaired.

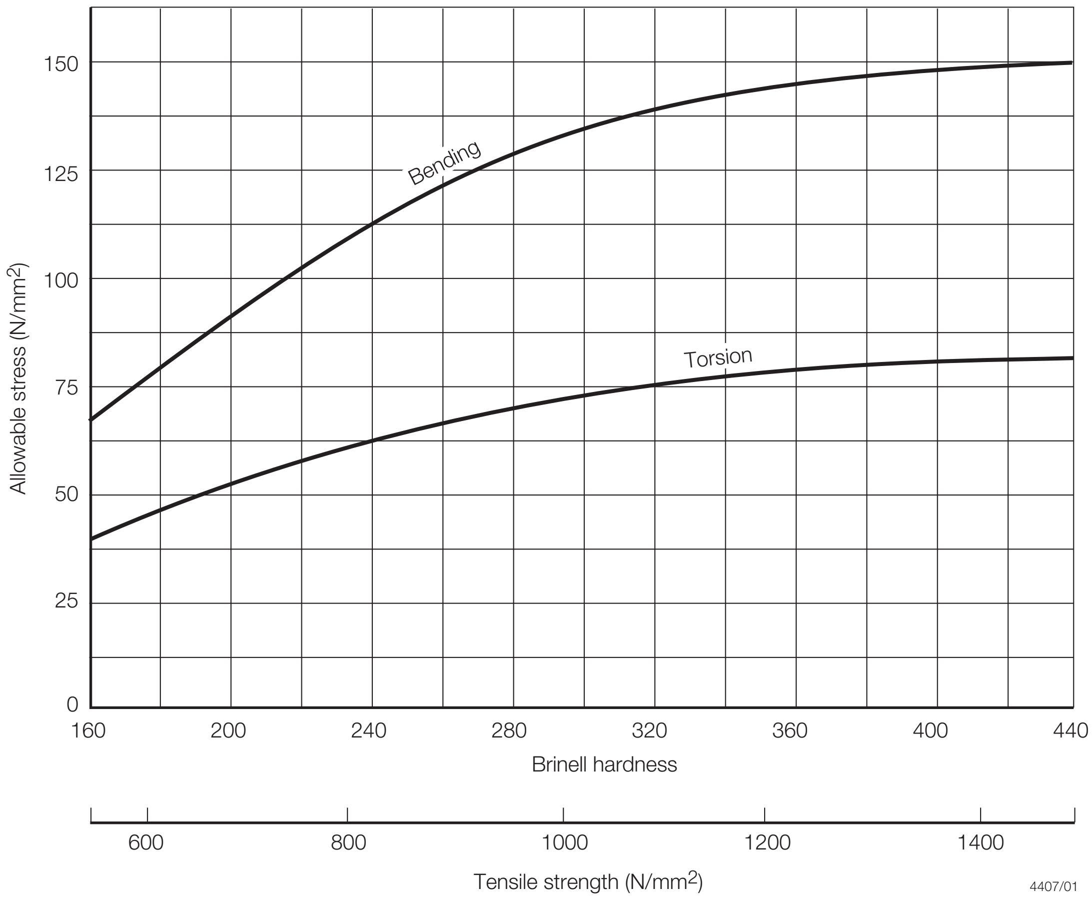

Fig. 23.3.1 Allowable stress – Shafting

3.8 Gear-case

3.8.1 The design of the attachment of the enclosed gearing gear-case to the jack-house or other supporting structure is to be such that the load reversals, where applicable, during jacking up and jacking down may be accommodated without relative movement between the gear-case and the jack-house.

3.9 Rack fixation system

3.9.1 When a rack fixation system is fitted, the design will be subject to special consideration.

■ *Section 4* Construction

4.1 Assembly design

4.1.1 The individual jacking gear units are to be designed such that each unit can be removed separately for inspection, maintenance and repair. Adequate arrangements for dismantling, including lifting devices, are to be provided.

4.1.2 Unless otherwise agreed, all gearing, except the main climbing pinion, are to operate in oil bath enclosures. Main pinions and racks are to be supplied with a suitable lubricant during all jacking operations.

4.1.3 Adequate inspection openings are to be provided to enable the teeth of pinions and gear wheels, and their attachment to the shafts, to be readily examined.

■ *Section 5* Inspection and testing

5.1 At jacking machinery manufacturers' works

5.1.1 The complete, assembled, jacking gear unit is to be subjected to a partial load running test with the first assembly for each new building tested to the maximum design jacking load (a minimum of one complete revolution of the main pinion) and the maximum static pre-load holding.

5.1.2 Upon satisfactory testing of the first jacking gear unit, the assembly is to be disassembled for inspection of all main components.

5.2 At the offshore unit construction site

5.2.1 Inspection and testing during construction and assembly is to be carried out to a plan/schedule acceptable to LR, but is to include the following:

(a) Jacking trials to verify satisfactory operation of the jacking machinery at all design jacking and holding load conditions.
(b) Jacking of hull/legs to the full extent of design travel to demonstrate satisfactory alignment of leg, racks, pinions and guides.
(c) Operation of the fixation system at various positions of leg/hull travel.
(d) Operation of the braking devices at the maximum design load to verify effective holding without slippage.

■ *Section 6*
Operation in ice

6.1 Additional requirements

6.1.1 *See* Pt 3, Ch 6 for additional requirements for operation in ice.

Rules and Regulations for the Classification of Mobile Offshore Units

Part 6
Control and Electrical Engineering

June 2013

LIFE MATTERS

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■ *Section 1* General requirements

1.1 General

1.1.1 The requirements of this Chapter apply to all mobile offshore units defined in Pt 1, Ch 2. Where applicable, the relevant requirements for control, alarm and safety systems as stated in Pt 6, Ch 1 of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships) are to be complied with.

1.1.2 Attention is also to be given to any relevant statutory requirements of the National Administration of the country in which the unit is to be registered and in the area of operation, as applicable.

1.1.3 These requirements apply to manned offshore units. Special consideration will be given to unmanned offshore units which are controlled from the shore or from another offshore installation.

1.1.4 Where reference is made in this Chapter to the requirements of the Rules for Ships, references therein to 'ship(s)' are to be understood to apply to 'unit(s)'.

1.2 Plans

1.2.1 Plans and particulars in 1.2.2 to 1.2.9 are to be submitted for design review.

1.2.2 Where control, alarm and safety systems are intended for machinery or equipment as defined in 1.2.3, the plans and particulars stated in Pt 6, Ch 1,1.2.2 of the Rules for Ships are to be submitted.

1.2.3 Plans for the control, alarm and safety systems of the following are to be submitted:

(a) **Propulsion and positioning systems**:
- Controllable pitch propellers.
- Dynamic positioning systems.
- Positional mooring and single point mooring systems.
- Propelling machinery including essential auxiliaries.
- Steering gear.
- Thruster-assisted positional mooring systems.
- Thruster units.

(b) **Utilities and services**:
- Air compressors.
- Bilge and ballast systems.
- Diving systems including compression chambers.
- Electric generating plant.
- Fixed water based local application fire-fighting systems.
- Evaporating and distilling systems.
- General service plant air and control and instrument air systems.
- Heating Ventilation and Air Conditioning (HVAC) systems including arrangements provided in respect of 1.3.5.
- Incinerators.
- Inert gas generators.
- Main propelling machinery including essential auxiliaries.
- Lifting appliances.
- Mechanical refrigeration systems.
- Oil fuel transfer and storage (purifiers and oil heaters).
- Oily water separators.
- Steam raising plant (boilers and their ancillary equipment).
- Steering gear.
- Cargo and ballast pumps in hazardous areas.
- Tempered water systems.
- Transverse thrust units.
- Waste heat boiler.
- Windlasses.
- Valve position indicating systems, *see* 2.7.
- Miscellaneous machinery (where control, alarm and safety systems are specified by other Sections of the Rules).
- Cargo tank, ballast tank and void space instrumentation where specified by other Sections of the Rules (e.g. water ingress detection, gas detection).

(c) **Process plant equipment**:
- Coalescers, skimmers and dehydrators.
- Export pumps and compressors.
- Gas compressors.
- Gas lift systems.
- Glycol contactors and regenerators.
- Heat exchangers.
- HP and LP flare systems.
- Process analysers.
- Production and test separator vessels.
- Production transfer and storage systems.
- Sand detection systems.
- Scrubbers.
- Sphere launching and receiving systems.
- Surge, flash and knock out drums.
- Water, gas and chemical injection systems.

- Well head, choke and header systems.
- Wireline systems.

(d) **Drilling plant equipment**:
- Blow out preventer stacks and diverter systems.
- Cement and barytes storage and handling systems.
- Choke and kill systems.
- Drawworks and eddy current brakes.
- Mud logging systems.
- Mud and cement pumps.
- Mud treatment systems.
- Rotary table.
- Wireline systems.

(e) **Riser systems**.

1.2.4 **Alarm systems**. Details of the overall alarm system, linking the main control station, subsidiary control stations, conning positions and where applicable the bridge area, the accommodation and other areas where duty personnel may be present, are to be submitted.

1.2.5 **Programmable electronic systems**. In addition to the documentation required by 1.2.2 and Pt 6, Ch 1,1.2.5 of the Rules for Ships, details of self-monitoring techniques are to be submitted.

1.2.6 **Wireless data communication**. For wireless data communication equipment the documentation required by Pt 6, Ch 1,1.2.6 of the Rules for Ships is to be submitted.

1.2.7 **Control stations**. Plans and particulars required to be submitted are given in Pt 6, Ch 1,1.2.7 of the Rules for Ships.

1.2.8 **Approved system**. Where it is intended to employ a standard system which has been previously approved, plans are not required to be submitted, providing there have been no changes in the applicable Rule requirements. The building port, where applicable, specific project and date of the previous approval is to be advised.

1.2.9 **Cables**. For details of instrumentation and control system cabling requirements, *see* Ch 2,11.

1.3 Control, alarm and safety equipment

1.3.1 The requirements for control, alarm and safety equipment are given in Pt 6, Ch 1,1.3 of the Rules for Ships, which are to be complied with.

1.3.2 Additions or amendments to these requirements are given in 1.3.3 to 1.3.4.

1.3.3 For fire and gas detection alarm systems, *see* Pt 7, Ch 1,2.2.9 and for programmable electronic systems, *see* Pt 6, Ch 1,2.10.5 and Pt 6 Ch 1,2.13.3 of the Rules for Ships.

1.3.4 Where equipment requires a controlled environment, alternative arrangements, whether permanently installed or of a temporary nature, are to be provided to maintain the required environment in the event of a failure of the normal air conditioning system, *see also* 3.15.14. Details of these arrangements are to be submitted for consideration.

1.4 Alterations and additions

1.4.1 The requirements for alterations and additions are given in Pt 6, Ch 1,1.4 of the Rules for Ships, which are to be complied with.

■ *Section 2*
Essential features for control, alarm and safety systems

2.1 General

2.1.1 Where it is proposed to install control, alarm and safety systems to the equipment defined in 1.2.3, the applicable features contained in Pt 6, Ch 1,2 of the Rules for Ships are to be incorporated in the system design.

2.2 Control stations for machinery and equipment

2.2.1 The requirements for control stations for machinery and equipment are given in Pt 6, Ch 1,2.2 of the Rules for Ships, which are to be complied with where applicable.

2.2.2 Additions or amendments to these requirements are given in 2.2.3 to 2.2.4.

2.2.3 Means of communication are to be provided as applicable between the main control station, subsidiary stations, the bridge area, the unit manager's office, the drill floor, the tool pusher's office and the accommodation for operating personnel.

2.2.4 For requirements regarding general emergency alarm systems, *see also* Pt 7, Ch 1,3.3.

2.3 Alarm systems

2.3.1 The general requirements for alarm systems are given in Pt 6, Ch 1,2.3 of the Rules for Ships, which are to be complied with.

2.4 Safety systems

2.4.1 Where safety systems are provided the requirements of Pt 6, Ch 1,2.4 of the Rules for Ships are to be satisfied. The requirements of this sub-Section apply, where relevant, to the safety systems installed on the equipment defined in 1.2.3, including those provided in addition to those safeguards required by Section 3 or Part 5.

2.4.2 Additions or amendments to these requirements are given in 2.4.3 to 2.4.4.

2.4.3 For emergency shut-down systems, *see also* Pt 7, Ch 1,7.

2.4.4 For safety system alarms, *see also* 3.1.4.

2.5 Control systems – General requirements

2.5.1 The requirements for control systems are given in Pt 6, Ch 1,2.5 of the Rules for Ships, which are to be complied with.

2.6 Manoeuvring controls for propulsion machinery

2.6.1 Where manoeuvring control systems for propulsion machinery are to be fitted, the requirements of Pt 6, Ch 1,2.6 of the Rules for Ships are to be complied with where applicable.

NOTES

1. The workstation(s) for navigation and manoeuvring and the conning position(s) will be located on the bridge of the unit, where such is provided. Where there is no designated bridge area, the requirements for workstation(s) and conning positions remain applicable, wherever their location.
2. Where separate workstations are provided for navigation and for manoeuvring, the requirements of this Section, and those of 4.2, are applicable to the latter.
3. Where the Rules for Ships refer to 'bridge control system', this should be understood to apply to propulsion control system.

2.6.2 Additions or amendments to these requirements are given in 2.6.3 to 2.6.5.

2.6.3 Instrumentation to indicate the following is to be fitted at the workstation(s) for navigation and manoeuvring and the conning position(s):

(a) Direction and speed of rotation of propeller for a fixed pitch propeller or pitch position for controllable pitch propeller, *see also* 3.9.
(b) Clutch position, where applicable.
(c) Shaft brake position, where applicable.
(d) For an azimuth thruster, direction and magnitude of thrust, and alarms and indications as detailed in Table 20.4.1 in Pt 5, Ch 20 of the Rules for Ships.

2.6.4 Azimuth thrust direction is to be controlled from the workstation(s) for navigation and manoeuvring, under all seagoing and manoeuvring conditions.

2.6.5 Two means of communication are to be provided between the workstation(s) for navigation and manoeuvring and the conning position(s) and the main control station in the machinery space. One of these means may be the propulsion control system; the other is to be independent of the main electrical power supply, *see also* 2.2.3 and Pt 5, Ch 1,4.7 of the Rules for Ships.

2.7 Valve control systems

2.7.1 The requirements for valve control systems are given in Pt 6, Ch 1,2.7 of the Rules for Ships, which are to be complied with where applicable.

2.7.2 Additions or amendments to these requirements are given in 2.7.3 to 2.7.4.

2.7.3 For ballast controls of column-stabilised units, *see also* 2.8.

2.7.4 For requirements applicable to closing appliances on scuppers and sanitary discharges, *see* Pt 4, Ch 7,10.1.

2.8 Ballast control systems for column-stabilised units

2.8.1 Column-stabilised units are to be provided with a ballast control system which meets the requirements of 2.8.2 to 2.8.8. The requirements for intact and damage stability and related definitions used in this Section are given in Pt 4, Ch 7, to which reference should be made.

2.8.2 A centralised ballast control station is to be provided from which all ballast operations can be performed. It is to be situated above zones of immersion after damage, as high as possible, as near a central position on the unit as is practicable, and adequately protected from the weather.

2.8.3 Control and instrumentation for the following is to be provided at the centralised control station:

(a) Ballast pump stop/start arrangements, status indicators, and control facilities.
(b) Ballast valve controls and position indication.
(c) Ballast tank level indication.
(d) Tank level indication of all tanks containing quantities of liquid that could affect stability of the unit, including fuel oil, fresh water, drilling water, and other stored liquids.
(e) Unit draught, heel and trim indication.
(f) Remote controls and indicators for watertight doors and hatch covers and other closing appliances, *see* Pt 7, Ch 1,9.
(g) Bilge and flood alarms, *see* Pt 7, Ch 1,9.
(h) Mooring line tension indication.

2.8.4 A permanently installed means of communication, independent of the unit's main source of electrical power, is to be provided between the centralised ballast control station and spaces that contain ballast pumps and services necessary for ballast operations, including local hand controls called for in 2.8.5.

2.8.5 In addition to the centralised controls required by 2.8.3(a) and (b), permanently installed local controls are to be provided to allow operation in the event of failure of the centralised controls.

2.8.6 The independent local controls for each ballast pump and its associated ballast tank valves are to be located in the same location, and a diagram of that part of the system is to be permanently displayed at the local control position.

2.8.7 The local controls are to be in readily accessible positions, and the associated access routes are to be situated inboard of the penetration zones after defined damage, *see* Pt 4, Ch 7,3.2. They are also to remain accessible and protected from the weather when the unit is in the intact and damaged condition.

2.8.8 Valve controls are to comply with 2.7 and, in addition, remote valve position indication systems are to function as independently as practicable of the control systems, *see also* Pt 5, Ch 13,11 and particularly Pt 5, Ch 13,11.4.

2.9 Programmable electronic systems – General requirements

2.9.1 The requirements for programmable electronic systems are given in Pt 6, Ch 1,2.10 of the Rules for Ships, which are to be complied with.

2.10 Data communication links

2.10.1 The requirements for data communication links are given in Pt 6, Ch 1,2.11 of the Rules for Ships, which are to be complied with.

2.11 Additional requirements for wireless data communication links

2.11.1 The requirements for wireless data communication links are given in Pt 6, Ch 1,2.12 of the Rules for Ships, which are to be complied with. The requirements are in addition to 2.10 and apply to systems incorporating wireless data communication links.

2.12 Programmable electronic systems – Additional requirements for essential services and safety critical systems

2.12.1 The requirements for programmable electronic systems incorporated in control, alarm or safety systems for essential services, as defined by Pt 6, Ch 2,1.5 or safety critical systems, are given in Pt 6, Ch 1,2.13 of the Rules for Ships, which are to be complied with.

2.12.2 Additions or amendments to these requirements are given in 2.12.3.

2.12.3 Input and output connections for safety critical systems (including emergency shut-down push button signals) are to be hard-wired, unless shown to meet the relevant requirements of Pt 7, Ch 1,7, for emergency shut-down systems. The transmission of the alarm and status information by digital means between the system and the supervisory workstation is permissible.

2.13 Programmable electronic systems – Additional requirements for integrated systems

2.13.1 The additional requirements for programmable electronic systems for integrated systems are given in Pt 6, Ch 1,2.14 of the Rules for Ships, which are to be complied with.

■ *Section 3* Control and supervision of unattended machinery

3.1 General

3.1.1 When machinery and equipment, as listed in 1.2.3, is fitted with automatic or remote controls so that under normal operating conditions it does not require any manual intervention by the operators, it is to be provided with the alarms and safety arrangements required by 3.2 to 3.15 as appropriate. Alternative arrangements which provide equivalent safeguards will be considered.

3.1.2 Where machinery is arranged to start automatically or from a remote control position, interlocks are to be provided to prevent start-up under conditions which could hazard the machinery.

3.1.3 Where machinery specified in Part 5 is required to be provided with a standby pump, the standby pump is to start automatically if the discharge pressure from the working pumps falls below a predetermined value.

3.1.4 Where a first stage alarm together with a second stage alarm and automatic shut-down of machinery are required in the relevant Tables of Part 5, the sensors and circuits utilised for the second stage alarm and automatic shut-down are to be independent of those required for the first stage alarm.

3.1.5 Where means are to be provided to prevent leaks from high pressure oil fuel injection piping for main and auxiliary engines dripping or spraying onto hot surfaces or into machinery air inlet. Such leakage is to be collected, where practicable, led to a collector tank(s) fitted in a safe position. An alarm is to be provided to indicate that leakage is taking place, *see* Pt 5, Ch 2,16 and associated Table 2.16.1. These requirements may also be applicable to high pressure hydraulic oil piping depending upon the location, *see* Pt 5, Ch 20,4.1.6.

3.1.6 Oil mist monitoring or engine bearing temperature monitors for crankcase protection are to be provided:

(a) when arrangements are fitted to override the automatic stop for excessive reduction of the lubricating oil supply pressure; and

(b) for engines of 2250 kW and above or having cylinders of more than 300 mm bore.

NOTES

1. For medium and high speed engines, automatic shut-down of the engine is to occur, *see also* 3.2.1.
2. For slow speed engines, automatic slow-down is to occur.
3. Where arrangements are made to override the automatic slow-down or shut-down due to high oil mist or bearing temperature, the override is to be independent of other overrides.
4. Where the bearing temperature monitoring method is chosen, all bearings in the crankcase are to be monitored where practicable, e.g. main, crankpin, crosshead.
5. Where engine bearing temperature monitors or alternative methods are provided for the prevention of the build-up of oil mist that may lead to a potentially explosive condition within the crankcase, details are to be submitted for consideration. The submission is to demonstrate that the arrangements are equivalent to those provided by oil mist monitoring. *See also* Pt 5, Ch 2,10.8.14 and 10.8.15 of the Rules for Ships.

3.2 Oil engines for propulsion purposes

3.2.1 Alarms and safeguards are indicated in Pt 5, Ch 2,7 of the Rules for Ships, which are to be complied with.

3.3 Steam turbine machinery

3.3.1 Alarms and safeguards are indicated in Pt 5, Ch 3,6 of the Rules for Ships, which are to be complied with.

3.3.2 Additions or amendments to these requirements are given in 3.3.3.

3.3.3 For steam turbines the requirements of Pt 5 Ch 3,4 for safety arrangements and Pt 5 Ch 3,5 for emergency arrangements are to be followed.

3.4 Gas turbine machinery

3.4.1 Alarms and safeguards are indicated in Pt 5, Ch 4,8 of the Rules for Ships, which are to be complied with.

3.4.2 Additions or amendments to these requirements are given in 3.4.3.

3.4.3 For gas turbines the requirements of Pt 5 Ch 4,8 for control, alarm and safety systems are to be followed.

3.5 Main, auxiliary and other boilers

3.5.1 Alarms and safeguards are indicated in Pt 5, Ch 10,18 of the Rules for Ships, which are to be complied with.

3.6 Thermal fluid heaters

3.6.1 Alarms and safeguards are indicated in Pt 5, Ch 14,12.2 of the Rules for Ships, which are to be complied with.

3.6.2 Additions or amendments to these requirements are given in 3.6.3.

3.6.3 The requirements in Pt 5, Ch 15,6 and associated Table 15.6.1 are to be followed.

3.7 Inert gas generators

3.7.1 Alarms and safeguards are indicated in Pt 5, Ch 14,12.3 of the Rules for Ships, which are to be complied with.

3.7.2 Additions or amendments to these requirements are given in 3.7.3 and 3.7.4.

3.7.3 Instrumentation and alarms are indicated in Pt 5, Ch 15,7.7.

3.7.4 For flue gas inert gas system requirements, *see* Pt 5, Ch 15,7 of the Rules for Ships.

3.8 Incinerators

3.8.1 Alarms and safeguards are indicated in Pt 5, Ch 14,13.2 and associated Table 14.13.2.

3.9 Auxiliary and other engines

3.9.1 Alarms and safeguards are indicated in Pt 5, Ch 2,7 of the Rules for Ships, which are to be complied with.

3.10 Controllable pitch propeller and transverse thrust units

3.10.1 Alarms and safeguards are indicated in Pt 5, Ch 7,5 of the Rules for Ships, which are to be complied with where applicable.

3.10.2 Additions or amendments to these requirements are given in 3.6.3.

3.10.3 Alarms and safeguards are indicated in Ch 2,15.5.

3.11 Podded propulsion units

3.11.1 Alarms and safeguards are indicated in Pt 5, Ch 9,8.2 and associated Table 9.8.1.

3.12 Oil storage and ballast pumps in hazardous areas

3.12.1 Alarms and safeguards are indicated in Pt 7, Ch 2,5.1.8 and associated Table 2.5.1.

3.13 Electric system

3.13.1 Alarms and safeguards are indicated in Ch 2,1.14.

3.14 Steering gear

3.14.1 For the requirements for steering gear, *see* Pt 5, Ch 19,5.3.

3.15 Miscellaneous services and machinery

3.15.1 Alarms and safeguards are indicated in Pt 5, Ch 14,12.5 of the Rules for Ships, which are to be complied with where applicable.

3.15.2 Additions or amendments to these requirements are given in 3.15.3 to 3.15.14.

3.15.3 Dual fuel systems. Indication for dual fuel systems is given in Pt 5, Ch 14,12.5.2 of the Rules for Ships, which are to be complied with. For oil and gas dual fired systems for boilers and engines, *see* Pt 5, Ch 16,1.

3.15.4 Lifts. For details of alarms and safeguards for lifts classed by LR, reference should be made to LR's *Code for Lifting Appliances in a Marine Environment*.

3.15.5 Oil heaters. Alarms and safeguards are given in Pt 5, Ch 14,12.5.4 of the Rules for Ships, which are to be complied with. For oil fuel or lubricating oil heaters, *see also* Pt 5, Ch 14,3.13.17.

3.15.6 Oil tank electric heating. Alarms and safeguards are given in Pt 5, Ch 14,12.5.5 of the Rules for Ships, which are to be complied with. For oil fuel and lubricating oil tanks that are provided with electric heating elements, *see* Pt 5, Ch 14,3.13.21.

3.15.7 Oil fuel tanks. Means are to be provided to eliminate the possibility of overflow from daily service oil fuel tanks into the machinery space and to safeguard against overflow of oil from the daily service oil fuel tanks through the air pipe together with termination of air pipes, *see also* Pt 5, Ch 13,12.5.

3.15.8 Sterntube. Alarms are given in Pt 5, Ch 14,12.5.1 of the Rules for Ships, which are to be complied with where applicable. Lubricating oil tank and bearing temperature, *see also* Pt 5, Ch 6,3.12.7 and 3.12.8.

3.15.9 Coolant tanks, feedwater tanks, and daily service tanks, settling tanks, and sludge tanks, *see* Pt 5, Ch 14,2.1.4, 2.9.10, 3.13.4, 13.1 and associated Table 14.13.1.

3.15.10 Oil fuel, *see* Pt 5, Ch 14,2.

3.15.11 Oil fuel and lubricating oil purifiers, *see* Pt 5, Ch 14 Sections 2, 4, 8, 13 and associated Table 14.3.1.

3.15.12 Air compressors, *see* Pt 5, Ch 14, Sections 10, 13 and associated Table 14.13.1.

3.15.13 Hydraulic power units, and control air systems, *see* Pt 5, Ch 14, Sections 8, 9, 13 and associated Table 14.13.1.

3.15.14 An alarm is to operate for abnormal controlled environmental conditions when equipment requires air conditioning, *see* Pt 5, Ch 14,13 and associated Table 14.13.1 and 1.3.4.

■ *Section 4* Unattended machinery space(s) – 'UMS' notation

4.1 General

4.1.1 The general requirements for unattended machinery space(s) are given in Pt 6, Ch 1,4.1 of the Rules for Ships, which are to be complied with.

4.1.2 Additions or amendments to these requirements are given in 4.1.3 to 4.1.5.

4.1.3 The requirements of this Section apply to all types of thrusters incorporated in the propulsion or positioning systems of the unit.

4.1.4 For this Section where the Rules for Ships refer to 'bridge', this is to be understood to apply to workstation(s) for navigation and manoeuvring.

4.1.5 For this Section where the Rules for Ships refer to 'engineering personnel', this is to be understood to apply to maintenance personnel.

4.2 Alarm system for machinery

4.2.1 An alarm system which will provide warning of faults in the machinery is to be installed. The system is to satisfy the requirements of 2.3.

4.3 Remote control of propulsion machinery

4.3.1 Where propulsion machinery is installed, it is to be provided with a remote control system operable at the workstation(s) for navigation and manoeuvring. The system is to satisfy the requirements of 2.6.

4.4 Control stations for machinery

4.4.1 Control station(s) are to be provided in the vicinity of the propulsion machinery and at workstation(s) for navigation and manoeuvring, and are to satisfy the requirements of 2.2.

4.5 Fire detection alarm system

4.5.1 An automatic fire detection system is to be fitted to protect all unattended spaces together with an audible and visual alarm system. The system is to satisfy the requirements of Pt 7, Ch 1,2.

4.6 Bilge level detection

4.6.1 The requirements for bilge level detection are given in Pt 6, Ch 1,4.6 of the Rules for Ships, which are to be complied with.

4.6.2 Additions or amendments to these requirements are given in 4.6.3.

4.6.3 A minimum of two independent systems of bilge level detection is to be provided in each machinery space that is situated below the water line. In addition each branch bilge as required by Pt 5, Ch 13,4 is to be provided with a level detector.

4.7 Supply of electric power – General

4.7.1 For units which operate with one generator set in service, arrangements are to be such that a standby generator will automatically start and connect to the switchboard on loss of the service generator. For units which operate with two or more generator sets in service, arrangements are to be such that on loss of one generator the remaining one(s) are to be adequate for continuity of essential services. For the detailed requirements of these arrangements, *see* Ch 2,2.2.

■ *Section 5* Machinery operated from a centralised control station – 'CCS' notation

5.1 General requirements

5.1.1 The requirements for machinery operated from a centralised control station are given in Pt 6, Ch 1,5.1 of the Rules for Ships, which are to be complied with.

5.1.2 Additions or amendments to these requirements are given in 5.1.3.

5.1.3 The controls, alarms and safeguards required by Section 3 and by 4.6 together with a fire detection system satisfying the requirements of Pt 7, Ch 1,2 are to be provided.

5.2 Centralised control system for machinery

5.2.1 The requirements for a centralised control system for machinery are given in Pt 6, Ch 1,5.2 of the Rules for Ships, which are to be complied with where applicable.

■ *Section 6* Integrated computer control – 'ICC' notation

6.1 General

6.1.1 Integrated Computer Control class notation **ICC** may be assigned where an integrated computer system in compliance with Pt 6, Ch 1,6 of the Rules for Ships provides fault tolerant control and monitoring functions for one or more of the following services:

- Propulsion and auxiliary machinery.
- Dynamic positioning systems.
- Positional mooring systems.
- Ballast systems.
- Process and utilities.
- Drilling equipment.
- Product storage and transfer systems.

6.1.2 Additions or amendments to these requirements are given in 6.1.3.

6.1.3 Pt 6, Ch 1,6.1.3 of the Rules for Ships is not applicable to offshore units.

6.2 General requirements

6.2.1 The integrated computer control system is to comply with the programmable electronic system requirements of 2.10 to 2.13, Pt 6, Ch 1,6.2 of the Rules for Ships and the control and monitoring requirements of the Rules applicable to particular equipment, machinery or systems.

6.2.2 Additions or amendments to these requirements are given in 6.2.3.

6.2.3 Alarm and indication functions required by 2.4 are to be provided by the integrated computer control system in response to the activation of any safety function for associated machinery. Systems providing the safety functions are in general to be independent of the integrated computer system, *see also* Pt 6, Ch 1,2.14.7 of the Rules for Ships.

6.3 Operator stations

6.3.1 The requirements for the operator stations are given in Pt 6, Ch 1,6.3 of the Rules for Ships, which are to be complied with.

6.3.2 Additions or amendments to these requirements are given in 6.3.3.

6.3.3 Where the integrated computer control system is arranged such that control and monitoring functions may be accessed at more than one operator station, the selected mode of operation of each station (e.g. in control, standby, etc.) is to be clearly indicated, *see also* 2.2.

■ *Section 7* Functional testing

7.1 General

7.1.1 The general requirements for the functional tests are given in Pt 6, Ch 1,7.1 of the Rules for Ships, which are to be complied with.

7.2 Unattended machinery space operation – 'UMS' notation

7.2.1 In addition to the tests required by 7.1, the requirements for the functional tests of **UMS** notation during final commissioning sea trials are given in Pt 6, Ch 1,7.2 of the Rules for Ships, which are to be complied with.

7.3 Operation from a centralised control station – 'CCS' notation

7.3.1 In addition to the tests required by 7.1, the requirements for the functional tests of **CCS** notation during final commissioning sea trials are given in Pt 6, Ch 1,7.3 of the Rules for Ships, which are to be complied with.

7.4 Record of trials

7.4.1 The requirements for the records of the trials are given in Pt 6, Ch 1,7.4 of the Rules for Ships, which are to be complied with.

■ *Section 8* Ergonomics of control stations

8.1 Control station layout

8.1.1 In order to take account of operator tasks at control stations, enhance usability and reduce human error, the layout arrangements are to comply with the requirements set out in Pt 6, Ch 1,3.2 of the Rules for Ships.

8.2 Physical environment

8.2.1 In order to establish a working environment that has minimum distractions, is sufficiently comfortable, helps maintain vigilance and maximises communication amongst operators at main control stations, the requirements in Pt 6, Ch 1,3.3 of the Rules for Ships, are to be complied with.

8.3 Operator interface, controls, display

8.3.1 The requirements in Pt 6, Ch 1,3.4 to 3.6 of the Rules for Ships apply to operator interfaces for essential engineering systems located either locally, remotely or within the main control room. The requirements are intended to enhance the usability of systems and equipment, reduce human error, enhance situational awareness and support safe and effective monitoring and control under normal and abnormal modes of operation.

Section

■ *Section 1* General requirements

1.1 General

1.1.1 The requirements of this Chapter apply to all mobile units defined in Pt 1, Ch 2 except where otherwise stated. Where applicable, the relevant requirements for electrical services necessary to maintain the unit in a normal sea-going, operational and habitable condition, for electrical services essential for safety and for the safety of crew and ship from electrical hazards as stated in Pt 6, Ch 2 of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships) are to be complied with.

1.1.2 Attention is also to be given to any relevant Statutory Regulations of the National Authority in the country in which the unit is to operate and/or be registered. Compliance with the Statutory Regulations of the National Authority may be accepted as meeting the requirements of the *International Convention for the Safety of Life at Sea, 1974*, and applicable amendments.

1.1.3 Where reference is made to the requirements of the Rules for Ships, references therein to 'ship(s)' are to be understood to refer to 'unit(s)'.

1.2 Plans

1.2.1 Plans and particulars in Pt 6, Ch 2,1.2 of the Rules for Ships are to be submitted for consideration:

NOTE

Where reference is made in the Rules for Ships to explosive gas atmospheres and/or combustible dusts, or to the electrical equipment for use in those areas, *see also* Pt 7, Ch 2,8 and Ch 2,9.

1.3 Plans required for supporting evidence

1.3.1 The plans and particulars in Pt 6, Ch 2,1.3 of the Rules for Ships are to be submitted as supporting evidence.

1.3.2 Additions or amendments to these requirements are given in 1.3.3.

1.3.3 A description of the philosophy of the systems of power generation and distribution, describing their modes of operation under normal and emergency conditions is to be submitted.

1.4 Surveys

1.4.1 The equipment required to be surveyed are given in Pt 6, Ch 2,1.4 of the Rules for Ships, which are to be complied with.

1.5 Additions or alterations

1.5.1 The requirements for additions or alterations are given in Pt 6, Ch 2,1.5 of the Rules for Ships, which are to be complied with.

1.6 Definitions

1.6.1 Definitions are given in Pt 6, Ch 2,1.6 of the Rules for Ships, as amended by 1.6.2 and 1.6.3.

1.6.2 Essential services are those necessary for the propulsion and safety of the unit, such as the following:
- Electric propulsion equipment.
- Thruster systems for dynamic positioning.
- Thruster systems for positional mooring.
- Abandonment systems dependent on electric power.
- Ventilation systems for hazardous areas and those maintained at an overpressure to exclude the ingress of dangerous gases.
- Wellhead control and disconnection systems dependent on electric power.
- Electric starting systems for oil engines.
- Other items as given in Pt 6, Ch 2,1.6.1 of the Rules for Ships.

1.6.3 Services such as the following, which are additional to those in Pt 6, Ch 2,1.6.1 and 1.6.2 of the Rules for Ships, and are considered necessary to maintain the unit in a normal operational and sea-going habitable condition:
- Drilling plant equipment.
- Processing and production equipment.
- Hotel services, other than those required for habitable conditions.
- Thrusters, other than those for essential services.
- Lifting appliances for the transfer of material, equipment or personnel.

1.7 Design and construction of equipment

1.7.1 The requirements for design and construction are given in Pt 6, Ch 2,1.7 of the Rules for Ships, which are to be complied with.

1.8 Quality of power supplies

1.8.1 The requirements for quality of power supplies are given in Pt 6, Ch 2,1.8 of the Rules for Ships, which are to be complied with.

1.9 Ambient reference conditions

1.9.1 The requirements for design and construction are given in Pt 6, Ch 2,1.9 of the Rules for Ships, which are to be complied with where applicable.

1.9.2 Additions or amendments to these requirements are given in 1.9.3 to 1.9.5.

1.9.3 The rating for classification purposes of essential electrical equipment is to be based on the maximum ambient air and water temperatures expected at the location of the unit. In the absence of precise temperatures, the following temperatures are to be assumed:

(a) For units intended to operate within the tropical belt (i.e., between latitudes 35°N and 20°S):
  Primary cooling water supply 32°C
  Cooling air temperature 45°C.

(b) For units intended to operate in northern or southern waters outside the tropical belt:
  Primary cooling water supply 25°C
  Cooling air temperature 40°C.

1.9.4 The air temperature range considered with respect to the selection of equipment, the safe operation of which may be subject to limitations on ambient temperature (e.g., safe-type electrical equipment), is to be that expected at the location of the equipment, taking into account local sources of heat and the range of ambient air temperature expected at the location of the unit. In the absence of precise information, the maximum air temperature is to be assumed to be the cooling air temperature given in 1.8.1(a) or (b), as appropriate, and the minimum is to be assumed to be minus 20°C, or as determined by reference to Annex B of IEC 61892-1: *Mobile and fixed offshore units – Electrical installations – Part 1: General requirements and conditions*.

1.9.5 Where electrical equipment is installed within environmentally controlled spaces, the ambient temperature for which the equipment is suitable for operation at its rated capacity may be reduced to a value not more than 10°C below that determined by reference to 1.9.3 or 1.9.4, provided that the requirements of Pt 6, Ch 2,1.9.4 of the Rules for Ships are complied with where applicable, *see also* Ch 1,1.3.3.

1.10 Inclination of the unit

1.10.1 The requirements for inclination of the unit are given in Pt 6, Ch 2,1.10 of the Rules for Ships, which are to be complied with where applicable.

1.10.2 Additions or amendments to these requirements are given in 1.10.3.

1.10.3 Essential and emergency electrical equipment is to operate satisfactorily under the conditions as shown in Table 2.1.1 for column-stabilised and self-elevating units.

Table 2.1.1 Inclination of other units

Installations, components	Angle of inclination, degrees in any direction			
	Column-stabilised units		Self-elevating units	
	Static	Dynamic	Static	Dynamic
Essential electrical equipment	15	22,5	10	15
Electrical equipment for emergency services	25	25	15	15

1.11 Location and construction of equipment

1.11.1 The requirements for location and construction are given in Pt 6, Ch 2,1.11 of the Rules for Ships, which are to be complied with.

1.11.2 Additions or amendments to these requirements are given in 1.11.3 to 1.11.5.

1.11.3 Electrical equipment, as far as is practicable, is to be located:

(a) Such that it is accessible for the purpose of maintenance and survey.
(b) Clear of flammable material.
(c) In spaces adequately ventilated to remove the waste heat liberated by the equipment under full load conditions, at the ambient conditions specified in 1.9.
(d) Where flammable gases cannot accumulate. If this is not practicable, electrical equipment is to comply with the relevant requirements of Pt 7, Ch 2,8.
(e) Where it is not exposed to the risk of mechanical injury or damage from water, steam or oil.

1.11.4 Equipment located in hazardous areas, or required to remain operational during catastrophic conditions, is to comply with the relevant requirements of Pt 7, Ch 2,8.

1.11.5 Where electrical power is used for propulsion, the equipment is to be so arranged that it will operate satisfactorily in the event of partial flooding by bilge water above the tank top up to the bottom floor plate level, under the normal angles of inclination given in 1.10 for essential electrical equipment, *see also* Pt 5, Ch 13.

1.12 Earthing of non-current-carrying parts

1.12.1 The requirements for earthing of non-current-carrying parts are given in Pt 6, Ch 2,1.12 of the Rules for Ships, which are to be complied with.

1.12.2 Additions or amendments to these requirements are given in 1.12.3.

1.12.3 Where the current-carrying conductor exceeds 125 mm^2, a 64 mm^2 earthing conductor is permitted, provided that the circuit protection arrangements are such as will prevent an excessive temperature rise under fault conditions. Every other earthing conductor is to have a conductance not less than that specified for an equivalent copper earthing conductor.

1.13 Bonding for the control of static electricity

1.13.1 The requirements for earthing of non-current-carrying parts are given in Pt 6, Ch 2,1.13 of the Rules for Ships, which are to be complied with.

1.13.2 Additions or amendments to these requirements are given in 1.13.3.

1.13.3 Bonding straps for the control of static electricity are required for storage tanks.

1.14 Alarms

1.14.1 The requirements for alarms are given in Pt 6, Ch 2,1.14 of the Rules for Ships which are to be complied with.

1.15 Labels, signs and notices

1.15.1 The requirements for labels, signs and notices are given in Pt 6, Ch 2,1.15 of the Rules for Ships, which are to be complied with.

1.16 Operation under fire conditions

1.16.1 The requirements for operation under fire conditions are given in Pt 6, Ch 2,1.16 of the Rules for Ships, which are to be complied with.

Note
Fire safety stops, *see also* Pt 7, Ch 1,2.4.
Low location lighting, *see also* Pt 7, Ch 1,3.5.

1.17 Operation under flooding conditions

1.17.1 The requirements for operation under fire conditions are given in Pt 6, Ch 2,1.17 of the Rules for Ships, which are to be complied with.

1.18 Protection of electrical equipment against the effects of lightning strikes

1.18.1 The requirements for protection of electrical equipment against the effects of lightning strikes are given in Pt 6, Ch 2,1.18 of the Rules for Ships, which are to be complied with.

1.19 Programmable electronic systems

1.19.1 The requirements for programmable electronic systems are given in Pt 6, Ch 2,1.19 of the Rules for Ships, which are to be complied with.

■ *Section 2*
Main source of electrical power

2.1 General

2.1.1 The main source of electrical power is to include at least two generating sets and is to comply with the requirements of this Section and Pt 6, Ch 2,2 of the Rules for Ships without recourse to the emergency source of electrical power.

2.2 Number and rating of generators and converting equipment

2.2.1 The requirements for the number and rating of generators and converting equipment are given in Pt 6, Ch 2,2.2 of the Rules for Ships, which are to be complied with where applicable.

NOTE

The requirements are applicable when a unit is underway (self-propelled or towed) or stationary engaged in its primary function (e.g., drilling, production or lifting).

2.2.2 Additions or amendments to these requirements are given in 2.2.3 to 2.2.4.

2.2.3 Automatic starting and connecting to the main switchboard of the standby set and automatic sequential restarting of essential services, *see* 1.6.1, in as short a time as is practicable.

2.2.4 Where the prime mover starting time will result in a starting and connection time in excess of 45 seconds, details are to be submitted for consideration.

2.3 Starting arrangements

2.3.1 The requirements for starting arrangements are given in Pt 6, Ch 2,2.3 of the Rules for Ships, which are to be complied with where applicable.

2.4 Prime mover governors

2.4.1 The requirements for prime mover governors are given in Pt 6, Ch 2,2.4 of the Rules for Ships, which are to be complied with.

2.5 Main propulsion driven generators not forming part of the main source of electrical power

2.5.1 The requirements for starting arrangements are given in Pt 6, Ch 2,2.5 of the Rules for Ships, which are to be complied with.

■ *Section 3* Emergency source of electrical power

3.1 General

3.1.1 The general requirements for emergency source of electrical power are given in Pt 6, Ch 2,3.3 of the Rules for Ships, which are to be complied with where applicable.

3.1.2 Additions or amendments to these requirements are given in 3.1.3 to 3.1.7.

3.1.3 The emergency source of electrical power, associated transforming equipment, if any, transitional source of emergency power, emergency switchboard and emergency lighting switchboard are to be located in a non-hazardous space above the uppermost continuous deck and above the worst damage waterline, inboard of the defined damage zones, *see* Pt 4, Ch 7,2 and Ch 7,3. They are not to be located forward of the collision bulkhead, if any.

3.1.4 The space containing the emergency source of electrical power, associated transforming equipment, if any, the transitional source of emergency electrical power and the emergency switchboard is not to be contiguous to the boundaries of hazardous areas.

3.1.5 The electrical power available is to be sufficient to supply all those services that are essential for safety in an emergency, due regard being paid to such services as may have to be operated simultaneously. The emergency source of electrical power is to be capable, having regard to starting currents and the transitory nature of certain loads, of supplying simultaneously at least the following services for the periods specified hereinafter, if they depend upon an electrical source for their operation:

(a) For a period of 18 hours, emergency lighting:
   - (i) in all service and accommodation alleyways, stairways and exits, personnel lift cars and personnel lift trunks;
   - (ii) in the machinery spaces and main generating stations including their control positions;
   - (iii) in all control stations, machinery control rooms, and at each main and emergency switchboard;
   - (iv) at all stowage positions for fireman's outfits;
   - (v) at the steering gear;
   - (vi) at the emergency fire pump, at the sprinkler pump, if any, and at the emergency bilge pump, if any, and at the starting positions of their motors;
   - (vii) in any stored oil pump-room;
   - (viii) at every survival craft preparation station, muster and embarkation station and over the sides;
   - (ix) on helicopter decks; and
   - (x) in all spaces from which control of the drilling process is performed and where controls of machinery essential for the performance of this process, or devices for emergency switching-off of the power plant are located.

(b) For a period of 18 hours:
   - (i) the navigation lights and other lights required by the *International Regulations for the Prevention of Collisions at Sea*, in force;
   - (ii) the radio communications as required by Amendments to SOLAS 1974, Chapter IV;
   - (iii) permanently installed diving equipment necessary for the safe conduct of diving operations, if dependent upon the unit's electrical power;
   - (iv) the emergency fire pump if dependent upon the emergency generator for its source of power;
   - (v) one of the refrigerated liquid carbon dioxide units intended for fire protection, where both are electrically driven;

(vi) on column-stabilised units: ballast valve control system, ballast valve position indicating system, draft level indicating system, tank level indicating system, and the largest single ballast pump required by Pt 5, Ch 13,11;

(vii) abandonment systems dependent on electric power;

(viii) helicopter deck perimeter lights and helideck status lights, wind direction indicator illumination, and related obstruction lights.

(c) For a period of 18 hours:

(i) the navigational aids as required by Amendments to SOLAS 1974 Regulations V/19 as applicable;

(ii) general alarm and communication systems required in an emergency;

(iii) intermittent operation of the daylight signalling lamp and the unit's whistle;

(iv) the fire and gas detection systems and their alarms;

(v) the capability of closing the blow out preventer and of disconnecting the unit from the wellhead arrangement, if electrically controlled,unless such services have an independent supply from an accumulator battery suitably located for use in an emergency and sufficient for the period of 18 hours.

(d) The steering gear for the period of time required by Pt 5, Ch 19,6.

(e) For a period of four days, any signalling lights or sound signals which may be required for marking offshore structures, unless such services have an independent supply from an accumulator battery suitably located for use in an emergency and sufficient for the period of four days.

(f) For a period of half an hour:

(i) power to operate any watertight doors but not necessarily all of them simultaneously, unless an independent temporary source of stored energy is provided; and

(ii) power to operate the controls and indicators provided.

(g) Where applicable, the services required by Pt 6, Ch 2,2.3.2 of the Rules for Ships.

3.1.6 The emergency source of electrical power may be either a generator or an accumulator battery, which is to comply with the requirements given in Pt 6, Ch 2,3.3.8 of the Rules for Ships.

3.1.7 The transitional source of emergency electrical power where required by 3.1.6 is to consist of an accumulator battery suitably located for use in an emergency which is to operate without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage and be of sufficient capacity and be so arranged as to supply automatically in the event of failure of either the main or the emergency source of electrical power for half an hour at least the following services if they depend upon an electrical source for their operation:

(a) the lighting required by 3.1.5(a). For this transitional phase, the required emergency electric lighting, in respect of the machinery space and accommodation and service spaces may be provided by permanently fixed, individual, automatically charged, relay operated accumulator lamps, and

(b) all services required by 3.1.5(b)(i) and (ii) and 3.1.5(c) unless such services have an independent supply for the period specified from an accumulator battery suitably located for use in an emergency.

3.2 Starting arrangements

3.2.1 Where the emergency source of power is a generator, the starting arrangements are to comply with the requirements given in Pt 5, Ch 2,8.14.

3.3 Prime mover governor

3.3.1 Where the emergency source of power is a generator, the governor is to comply with 2.4.

3.4 Radio installation

3.4.1 The requirements for radio installation are given in Pt 6, Ch 2,3.6 of the Rules for Ships, which are to be complied with.

3.5 Accommodation units

3.5.1 The emergency source of electrical power in units carrying more than 50 persons, who are not crew members or passengers, is to comply with the requirements of Pt 3, Ch 4,4.

■ *Section 4* External source of electrical power

4.1 Temporary external supply

4.1.1 The requirements for temporary external supply are given in Pt 6, Ch 2,4.1 of the Rules for Ships, which are to be complied with.

4.2 Permanent external supply

4.2.1 Details are to be submitted.

Section 5
Supply and distribution

5.1 Systems of supply and distribution

5.1.1 The requirements for systems of supply and distribution are given in Pt 6, Ch 2,5.1 of the Rules for Ships, which are to be complied with where applicable.

5.1.2 Additions or amendments to these requirements are given in 5.1.3.

5.1.3 The systems of generation and distribution that are generally acceptable are:
(a) d.c., two-wire;
(b) a.c., single-phase, two-wire; and
(c) a.c., three-phase; three-wire; or four-wire with neutral earthed but without hull return.
(d) a.c., high voltage, three-phase, three-wire, with neutral earthed through a resistor or other impedance.

5.2 Essential services

5.2.1 The requirements for essential services are given in Pt 6, Ch 2,5.2 of the Rules for Ships, which are to be complied with.

5.3 Isolation and switching

5.3.1 The requirements for isolation and switching are given in Pt 6, Ch 2,5.3 of the Rules for Ships, which are to be complied with.

5.4 Insulated distribution systems

5.4.1 The requirements for insulated distribution systems are given in Pt 6, Ch 2,5.4 of the Rules for Ships, which are to be complied with.

5.5 Earthed distribution systems

5.5.1 The requirements for earthed distribution systems are given in Pt 6, Ch 2,5.5 of the Rules for Ships, which are to be complied with.

5.6 Diversity factor

5.6.1 The requirements for the diversity factor are given in Pt 6, Ch 2,5.6 of the Rules for Ships, which are to be complied with.

5.7 Lighting circuits

5.7.1 The requirements for lighting circuits are given in Pt 6, Ch 2,5.7 of the Rules for Ships, which are to be complied with.

5.7.2 Additions or amendments to these requirements are given in 5.7.3 and 5.7.4.

5.7.3 Where lighting circuits in a stored oil pump-room adjacent to a storage tank are also used for emergency lighting, and have been interlocked with ventilation, the interlocking arrangements are:
- not to cause the lighting to go out following a failure of the ventilation system; and
- not to prevent operation of the emergency lighting following the loss of the main source of electrical power.

5.8 Motor circuits

5.8.1 A separate final sub-circuit is to be provided for every motor for essential services, *see* 1.6.1.

5.9 Motor control

5.9.1 The requirements for motor control diversity factor are given in Pt 6, Ch 2,5.9 of the Rules for Ships, which are to be complied with.

Section 6
System design – Protection

6.1 General

6.1.1 The general requirements for protection are given in Pt 6, Ch 2,6.1 of the Rules for Ships, which are to be complied with.

6.2 Protection against short-circuit

6.2.1 The general requirements for protection against short-circuit are given in Pt 6, Ch 2,6.2 of the Rules for Ships, which are to be complied with..

6.3 Protection against overload

6.3.1 The general requirements for protection against overload are given in Pt 6, Ch 2,6.3 of the Rules for Ships, which are to be complied with.

6.4 Protection against earth faults

6.4.1 The general requirements for protection against short-circuit are given in Pt 6, Ch 2,6.4 of the Rules for Ships, which are to be complied with.

6.4.2 Additions or amendments to these requirements are given in 6.4.3.

6.4.3 Where a circuit passes into any zone 0 area, the protective systems shall be arranged so that manual intervention is necessary for the reconnection of the circuit after disconnection as the result of a short-circuit, overload or earth-fault condition.

6.5 Circuit breakers

6.5.1 The requirements for circuit breakers are given in Pt 6, Ch 2,6.5 of the Rules for Ships, which are to be complied with.

6.6 Fuses

6.6.1 The requirements for fuses are given in Pt 6, Ch 2,6.6 of the Rules for Ships, which are to be complied with.

6.7 Circuit breakers requiring back-up by fuse or other device

6.7.1 The requirements for circuit breakers requiring back-up by fuse or other devices are given in Pt 6, Ch 2,6.7 of the Rules for Ships, which are to be complied with.

6.8 Protection of generators

6.8.1 The requirements for the protection of generators are given in Pt 6, Ch 2,6.8 of the Rules for Ships, which are to be complied with.

6.9 Load management

6.9.1 The requirements for load management are given in Pt 6, Ch 2,6.9 of the Rules for Ships, which are to be complied with where applicable.

6.9.2 Additions or amendments to these requirements are given in 6.9.3.

6.9.3 Arrangements are to be made to disconnect automatically, after an appropriate time delay, circuits of the categories noted below, when the generator(s) is/are overloaded, sufficient to ensure the connected generating set(s) is/are not overloaded:

- non-essential circuits;
- circuits feeding services for habitability, *see* Pt 6, Ch 2,1.5.2 of the Rules for Ships; and
- circuits for other essential services, when it can be established that safe operation can be maintained during the temporary loss of such services.

6.10 Feeder circuits

6.10.1 The requirements for feeder circuits are given in Pt 6, Ch 2,6.10 of the Rules for Ships, which are to be complied with.

6.11 Motor circuits

6.11.1 The requirements for motor circuits are given in Pt 6, Ch 2,6.11 of the Rules for Ships, which are to be complied with.

6.12 Protection of transformers

6.12.1 The requirements for protection of transformers are given in Pt 6, Ch 2,6.12 of the Rules for Ships, which are to be complied with where applicable.

6.13 Harmonic filters

6.13.1 The requirements for protection of transformers are given in Pt 6, Ch 2,6.13 of the Rules for Ships, which are to be complied with.

■ *Section 7*
Switchgear and control gear assemblies

7.1 Construction and testing

7.1.1 The requirements for construction and testing of switchgear and control gear assemblies and their components are given in Pt 6, Ch 2,7 of the Rules for Ships, which are to be complied with.

7.2 Position of switchboards

7.2.1 The requirements for position of switchboards are given in Pt 6, Ch 2,7.16 of the Rules for Ships, which are to be complied with where applicable.

7.2.2 Additions or amendments to these requirements are given in 7.2.3.

7.2.3 So far as possible, pipes should not be installed directly above or in front of or behind switchboards, section boards and distribution boards. If such placing is unavoidable, suitable protection is to be provided in these positions, *see* Pt 5, Ch 13,2.

Section 8
Protection from electric arc hazards within electrical equipment

8.1 Hazard identification, calculations and testing

8.1.1 The requirements for protection from electric arc hazards within electrical equipment are given in Pt 6, Ch 2,8 of the Rules for Ships, which are to be complied with.

Section 9
Rotating machines

9.1 Construction, performance, control and testing

9.1.1 The requirements for construction, performance, control and testing of rotating machines are given in Pt 6, Ch 2,9 of the Rules for Ships, which are to be complied with.

9.1.2 Additions or amendments to these requirements are given in 9.2.

9.2 Temperature rise

9.2.1 The limits of temperature rise specified in Table 2.9.1 in Pt 6, Ch 2 of the Rules for Ships are based on the cooling air temperature and cooling water temperature given in 1.8.1(a).

9.2.2 If it is known that the temperature of cooling medium exceeds the values given in 1.8.1(a) the permissible temperature rise is to be reduced by an amount equal to the excess temperature of the cooling medium.

9.2.3 If it is known that the temperature of cooling medium will be permanently less than the values given in 1.8.1(a) the permissible temperature rise may be increased by an amount equal to the difference between the declared temperature and that given in 1.8.1(a), up to a maximum of 15°C.

Section 10
Converter equipment

10.1 Transformers

10.1.1 The requirements for transformers are given in Pt 6, Ch 2,10.1 of the Rules for Ships, which are to be complied with.

10.1.2 Additions or amendments to these requirements are given in 10.1.3.

10.1.3 Transformers are to comply with the requirements of IEC Publications 60076: *Power transformers*, or an acceptable and relevant National Standard amended where necessary for ambient temperature, *see* 1.8.

10.2 Semi-conductor equipment

10.2.1 The requirements for semi-conductor equipment are given in Pt 6, Ch 2,10.2 of the Rules for Ships, which are to be complied with.

10.2.2 Additions or amendments to these requirements are given in 10.2.3.

10.2.3 Semi-conductor equipment is to comply with the requirements of IEC 60146: *Semi-conductor Converters*, or an acceptable and relevant National Standard amended where necessary for ambient temperature, *see* 1.8.

10.3 Uninterruptible power systems (UPS)

10.3.1 The requirements for uninterruptible power systems are given in Pt 6, Ch 2,10.3 of the Rules for Ships, which are to be complied with.

10.3.2 Additions or amendments to these requirements are given in 10.3.3.

10.3.3 UPS units are to comply with the requirements of IEC 62040: *Uninterruptible power systems*, or an acceptable and relevant National Standard amended where necessary for ambient temperature, *see* 1.8.

Section 11
Electrical cables and busbar trunking systems (busways)

11.1 Construction, selection, installation and testing

11.1.1 The requirements for construction, selection, installation and testing of electrical cables are given in Pt 6, Ch 2,11 of the Rules for Ships, which are to be complied with.

11.1.2 Additions or amendments to these requirements are given in 11.2.

11.2 Busbar trunking systems (bustrunks)

11.2.1 Where the busbar trunking system is employed for circuits on and below the freeboard deck, arrangements are to be made to ensure that circuits on other decks are not affected in the event of partial flooding under the normal angles of inclination given in 1.10 for essential electrical equipment.

Section 12
Batteries

12.1 Secondary batteries of the vented and valve regulated sealed type

12.1.1 The requirements for batteries of the vented and valve regulated sealed type are given in Pt 6, Ch 2,12 of the Rules for Ships, which are to be complied with.

Section 13
Equipment – Heating, lighting and accessories

13.1 Heating and cooking equipment, lighting, socket outlets and plugs and enclosures

13.1.1 The requirements for heating and cooking equipment, lighting, socket outlets and plugs, and equipment enclosures are given in Pt 6, Ch 2,13 of the Rules for Ships, which are to be complied with.

Section 14
Signalling lights and sound signals

14.1 General

14.1.1 Signalling lights or sound signals required for marking offshore structures are to be fed from an emergency source of electrical power, *see* 3.1.5(e).

Section 15
Navigation and manoeuvring systems

15.1 Steering gear

15.1.1 The requirements for steering gear are given in Pt 6, Ch 2,15.1 of the Rules for Ships, which are to be complied with.

15.1.2 Additions or amendments to these requirements are given in 15.1.3.

15.1.3 These requirements are to be read in conjunction with those in Pt 5, Ch 19.

15.2 Thruster systems for steering

15.2.1 Where azimuth or rotatable thruster units, used as the sole means of steering, are electrically driven, the requirements of Pt 5, Ch 20 are to be complied with.

15.3 Thruster systems for dynamic positioning

15.3.1 For units having a **DP** class notation the requirements of Pt 3, Ch 9 are to be complied with.

15.4 Thruster systems for manoeuvring

15.4.1 Where a thruster system is fitted solely for the purpose of manoeuvring, and is electrically driven the requirements of Pt 6, Ch 2,15.4 of the Rules for Ships are to be complied with.

15.5 Transverse thrust units

15.5.1 Where transverse units are remotely controlled, the requirements of Pt 6, Ch 2,15.5 of the Rules for Ships are to be complied with.

15.6 Thruster systems for thruster-assisted mooring systems

15.6.1 For units having a thruster-assisted mooring class notation the requirements of Pt 3, Ch 10 are to be complied with.

15.7 Navigation lights

15.7.1 The requirements for navigation lights are given in Pt 6, Ch 2,15.6 of the Rules for Ships, which are to be complied with.

15.7.2 Additional requirements with respect to unit types as indicated in this Section should also be complied with as applicable as in 15.7.3.

15.7.3 Navigation lights are to be connected separately to a distribution board reserved for this purpose only, and accessible to the officer of the watch. The distribution board is to be connected directly or through transformers to the emergency source of electrical power in compliance with 3.1.5(b)(i) and 3.1.7(a).

15.8 Navigational aids

15.8.1 Navigational aids as required by SOLAS are to be fed from the emergency source of electrical power, *see also* Pt 6, Ch 2,3.3.7(d)(ii) of the Rules for Ships, which are to be complied with.

Section 16
Electric propulsion

16.1 General

16.1.1 The requirements for electric propulsion are given in Pt 6, Ch 2,16 of the Rules for Ships, which are to be complied with. This Section applies to self-propelled units or units which use their thrusters to stay on station. Thruster systems fitted for the purpose of manoeuvring or steering are to comply with Section 15.

Section 17
Testing and trials

17.1 Testing

17.1.1 The requirements for testing are given in Pt 6, Ch 2,21.1 of the Rules for Ships, which are to be complied with.

17.2 Trials

17.2.1 The requirements for trials are given in Pt 6, Ch 2,21.2 of the Rules for Ships, which are to be complied with.

17.3 High voltage cables

17.3.1 The requirements for high voltage cables are given in Pt 6, Ch 2,21.3 of the Rules for Ships, which are to be complied with.

17.4 Hazardous areas

17.4.1 The requirements for testing of electrical equipment located in hazardous areas are given in Pt 6, Ch 2,21.4 of the Rules for Ships, which are to be complied with where applicable.

NOTE
For hazardous areas, *see* Pt 7, Ch 2.

Section 18
Spare gear

18.1 General

18.1.1 The general requirements for spare gear are given in Pt 6, Ch 2,22.1 of the Rules for Ships, which are to be complied with where applicable.

Rules and Regulations for the Classification of Mobile Offshore Units

Part 7
Safety Systems, Hazardous Areas and Fire
June 2013

Lloyd's Register

LIFE MATTERS

Chapter Contents

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Part 7

■ *Section 1* General requirements

1.1 General

1.1.1 This Chapter applies to all units defined in Pt 1, Ch 2 on board which drilling, production and processing of hydrocarbons and/or storage of crude oil in bulk is undertaken. It is also applicable to Accommodation Units and Support Units as detailed in Pt 3, Ch 4. However, Accommodation Units and Support Units not engaged in activities with drilling, production and processing of hydrocarbons and/or storage of crude oil in bulk units need not comply with all the requirements of Section 2, in relation to gas detection, or the requirements of Sections 5, 6, 7 or 8 of this Chapter. This Chapter also states the fire detection requirements for units to be assigned the **UMS** and **CCS** notations, *see* Pt 6, Ch 1, Sections 4 and 5. Attention is to be given to the relevant Statutory Regulations of the National Administrations in the country of registration and area of operation, as applicable.

1.1.2 While Chapter 2 prescribes the boundaries of hazardous areas where special precautions are to be applied, the safeguards called for in this Chapter include provision for actions applicable where gas is present beyond hazardous area boundaries. Such circumstances may arise, for example, as the consequence of an uncontrolled well blow out or catastrophic failure of pipes or vessels.

1.1.3 These requirements apply to manned units. Special consideration will be given to unmanned units which are controlled from the shore or from another unit. When accommodation and support units are to operate for prolonged periods adjacent to live offshore hydrocarbon exploration or production units, it is the responsibility of the Owner/Operator to comply with the requirements of the appropriate National Administrations and special consideration will be given to the safety requirements for classification purposes, as appropriate.

1.1.4 Section 2 states general requirements for fire and gas detection systems. This Section also includes the additional fire detection requirements applicable for unattended machinery spaces and machinery spaces under continuous supervision from a centralised control station, *see* Pt 6, Ch 1,4 and Ch 1,5, and incorporates requirements for accommodation and support units with spaces to house offshore personnel who are not members of the crew of the unit, *see* Pt 3, Ch 4.

1.1.5 Section 3 states requirements for personnel warning systems, general alarms and public address systems.

1.1.6 Section 4 states requirements for emergency lighting equipment.

1.1.7 Section 5 states the alarms and safeguards required for heating, ventilation and air conditioning systems to protect against ingress of gas into safe areas, as defined in Chapter 2.

1.1.8 Section 6 states requirements which apply where ventilation systems are installed in enclosed and semi-enclosed hazardous areas, as defined in Ch 2,1.2.

1.1.9 Section 7 states requirements which apply to reduce fire and gas hazards in an emergency by shutting down process plant and machinery.

1.1.10 Section 8 states requirements for control and alarms of riser systems for the assignment of the special features class notation **PRS**.

1.1.11 Section 9 states requirements for the alarm and control of watertight closing appliances as required by Pt 4, Ch 7 and the requirements for the warning of ingress of water.

1.2 Plans

1.2.1 The following plans and documentation, as far as applicable to the unit, are to be submitted for review/approval:

(a) For fire and gas systems:
- Fire and gas system design philosophy document.
- Fire and gas system design specification.
- Loss control or hazard analysis charts.
- Block diagram showing interface and power supply arrangements.
- Fire and gas system ‘cause and effect’ diagrams, including actions on heating, ventilating and air conditioning systems.
- Layout drawing showing the positions of fire and gas detector heads, manually operated call points, control panels and repeaters, cable routes, and fire zones.
- Details of the make and type numbers of all detector heads, manual call points and associated panels.
- Fire pump control, alarm, starting and inhibiting arrangements.
- For programmable electronic systems and networked systems, *see also* Pt 6, Ch 1,2.5 and 2.9 to 2.12.

(b) For public address and general alarms, unit status indicators and emergency lighting:
- Communications philosophy document.
- Block diagrams showing interfaces and power supply arrangements.
- Single line diagrams.
- Unit layout drawings showing location of fire zones, equipment and cable routes.
- For programmable electronic systems and networked systems, *see also* Pt 6, Ch 1,2.5 and 2.9 to 2.12.

(c) For protection against gas in safe and hazardous areas:
- Layout drawing of drilling and/or process equipment and gas detectors.
- Ventilation system flow diagrams and gas detectors.

(d) For emergency lighting:
- Single line diagram.
- General arrangement plans showing the location of equipment and cable routes.

(e) For emergency shut-down systems (ESD) Systems:
- ESD philosophy document.
- Safety analysis tables based on results of HAZOP studies/reports.
- ESD safety analysis function evaluation charts (cause and effect matrices).
- Performance standards and criteria of the safety critical system.
- Safety integrity level categorisation study for the instrument protective system.
- Instrument protective system reliability and availability calculations report.
- Alarm and trip schedules.
- Block diagrams showing interfaces and power supply arrangements.
- Physical arrangement of control panel.
- Details of manual trips, resets and override facilities.
- Layout drawings showing positions of the ESD system control panel, subpanels and manual trips.
- Wellhead and riser valve hydraulic schematics and control panels.
- ESD valve pneumatic and/or hydraulic schematics.
- For programmable electronic systems and networked systems, *see also* Pt 6, Ch 1,2.5 and 2.9 to 2.12.

(f) For watertight doors and other electrically operated closing appliances:
- Single line diagram.
- General arrangement plans showing the location of equipment and cable routes.

1.3 Safety and communications equipment

1.3.1 Requirements for construction, detailed design, survey, inspection and testing of electrical and electronic equipment are contained in Pt 6, Ch 1 and Ch 2 respectively.

1.3.2 Requirements for construction, detailed design, survey, inspection and testing of pneumatic and hydraulic equipment are contained in Pt 5, Ch 1, Ch 12 and Ch 14.

1.3.3 Equipment used in safety and communication systems should be suitable for its intended purpose, and accordingly, whenever practicable, should be selected from the *List of Type Approved Products* published by LR. A copy of the *Procedure for LR Type Approval System* will be supplied on application. For fire detection alarm systems, *see* 2.2.9. For networked and programmable electronic systems, *see* Pt 6, Ch 1, 2.9 to 2.12.

1.3.4 Where equipment requires a controlled environment, an alternative means is to be provided to maintain the required environment in the event of a failure of the normal air conditioning system, *see* Pt 6, Ch 1,1.3.5 and 3.13.12.

1.3.5 Assessment of performance parameters, such as accuracy, repeatability, etc., are to be in accordance with an acceptable National or International Standard.

■ *Section 2*
Fire and gas alarm indication and control systems

2.1 General requirements

2.1.1 This Section states general requirements for fire and gas detection alarm indication and control systems. *See also* Sections 5, 6 and 7 for requirements concerning protection against gas leakage and shut-downs for process systems and associated equipment.

2.2 Fire and gas detection alarm panels and sensors

2.2.1 The requirements for fire detection alarm panels and sensors are given in Pt 6, Ch 1,2.8 of the Rules for Ships. These Rules are also to be complied with, where applicable, for gas detection alarm panels and sensors and fire detection alarm panels and sensors specific to the unit's requirements. For drilling units, specific reference should be made to the requirements of the 2009 IMO MODU Code Resolution A.1023(26) Ch 9 regarding fire and gas detection.

2.2.2 Automatic fire and gas detection alarm panels and sensors that satisfy the requirements of 2.2.3 to 2.2.14 are to be fitted. Additional requirements for accommodation spaces and machinery spaces are given in 2.5 and 2.6.

2.2.3 A fire and gas detection indicating panel is to be located at the main control station. A repeater panel is to be provided at a location which is readily accessible to responsible members of the crew at all times, at the fire-control station, if fitted, and at or adjacent to the workstation for navigation and manoeuvring or the workstation for safety, if fitted. The main panel and the fire-control station repeater are to indicate the source of the fire in accordance with arranged fire zones by means of a visual signal. Any other repeater panel(s) should indicate the general area of the fire zones affected.

2.2.4 An audible fire and gas alarm is to be provided having a characteristic tone(s), distinguishable from any other alarm. The audible alarm is to be immediately audible in all parts of the navigating bridge, if fitted, the workstations for navigation and manoeuvring, the fire control station, if fitted, all accommodation areas (with the exception, on accommodation units, of those for offshore personnel), and machinery spaces. The alarm need not be an integral part of the detection system.

2.2.5 Facilities are to be provided in the fire and gas detecting system to initiate manually the alarm in 2.2.4 from the following locations, in addition to the locations required by the Rules for Ships:

- Accommodation areas.
- The Unit Manager's office.
- Control stations in machinery and process areas.
- The main control station or fire-control station, if fitted.

2.2.6 Fire and gas detection and alarm systems are to be provided with an emergency source of electrical power as required by Pt 6, Ch 2,3 and are also to be connected to the main source of electrical power, with automatic changeover facilities located in, or adjacent to, the main fire detection indicator panel, *see also* Pt 6, Ch 2,3.1.5(c)(iv). Reference should also be made to the guidance given in ISO 13702 to the supply capacity of UPS systems to defined emergency/critical facilities for the MOU. Failure of any power supply is to initiate an audible and visual alarm, *see also* Pt 6, Ch 1,2.8.6 of the Rules for Ships.

2.2.7 Fire and gas detectors are to be grouped as appropriate into zones conforming to passive fire protection boundaries and/or safe/hazardous area boundaries as defined in Chapter 2 of these Rules. Further zones subdividing the above boundaries may also be arranged where beneficial. Factors influencing zone boundaries include ventilation arrangements, bulkheads and the needs of the operating staff in locating and dealing with fire and gas incidents.

2.2.8 A zone/section of fire detectors which covers a control station, a service space or an accommodation space is not to include a machinery space or process area.

2.2.9 Fire and gas control and indicator panels, repeater panels, detector heads, manual call points and short-circuit isolation units are to be suitable for their intended purpose. Where practicable, these should be selected from LR's *List of Type Approved Products*. The fire control system, as required by 2.5, is to be integrated with the main control panel.

2.2.10 When it is intended that a particular loop or detector is to be temporarily switched off, reactivation need not be automatic after a preset time.

2.2.11 Fire detector heads for the process and wellhead area, fusile plugs and linear electric elements for direct actuating of the deluge system may be used to supplement the automatic fire detection system.

2.2.12 Gas detectors are to be selected having regard to the flammable and/or toxic gases potentially present in each particular area or compartment and are to be sited having regard to the probable dispersal of the gas as governed by density, HVAC air flows and possible points of leakage, *see also* Sections 5 and 6.

2.2.13 Means are to be provided so that the sensitivity of gas detectors can be readily tested in their mounted positions by the injection of span gas or other equivalent method.

2.2.14 In addition to the fixed gas detection system, portable gas detectors of each of the following types, together with any necessary test facilities for checking their accuracy, are to be provided for all anticipated gas hazards including the following:

- Hydrocarbon gas detectors range 0 to 100 per cent of the lower explosive limit.
- Toxic gas detectors.
- Oxygen concentration meters.

2.3 Fire-extinguishing systems

2.3.1 The fire and gas detection system is to be arranged to initiate manually and automatically appropriate extinguishing system control actions by:

- Actuating fire-fighting media and pre-release warnings.
- Initiating fire and gas damper closures and stopping of ventilation fans to reduce the effect of fire and minimise ingress of gas.
- Starting fire pumps.

The arrangements are to comply with 2.3.2 to 2.3.10.

2.3.2 The operational state of fire-extinguishing facilities, including smothering gas, deluge, foam equipment and fire water systems, are to be displayed on the main control panel and the fire-control point repeater panel, if fitted, as follows:

- Charges of gas available for use, indication of zones into which gas has been released, and reserve capacity in hand.
- Indication of zones in which water deluge has been initiated.
- Liquid level in main installation (i.e., deck foam system, etc.), foam concentrate tank(s) and status of foam concentrate pumps and valves.
- Availability of fire pumps, indication of running and standby sets and positions of associated valves.
- Operational state of sprinkler systems.

2.3.3 The provision of manual and automatic release facilities for extinguishing media is to be designed to afford optimum protection to the installation while giving proper regard to the safety of personnel, as follows:

(a) Generally, the release of asphyxiating gases such as carbon dioxide should only be initiated locally by manual means since it is necessary to ensure that the space to be dealt with has been evacuated.

(b) Deluge systems and extinguishing gases which can be released without introducing an unacceptable health risk should be capable of being released locally and remotely at the fire and gas indication and control panel and at the fire-control station, if fitted. Automatic release of media by the voting action of grouped fire detectors within a zone is recommended, especially for spaces carrying a high potential fire risk.

2.3.4 Fire pumps are to be provided with automatic and manual starting facilities on the fire and gas detection indication and control panel. Automatic starting is to be initiated by activation of fire detection heads, operation of any manual call points or reduction of pressure in the fire main. Controls which start the standby set in the event of starting or running failure of the duty set are to be provided. Safeguards required in the event of flammable gas being detected in the vicinity of the fire pump are detailed under 5.1.9. Manual starting facilities are to be provided adjacent to all fire pumps.

2.3.5 The design of the extinguishing systems is to be in accordance with SOLAS Ch II-2 Reg 10 and IMO Fire Fighting System (FSS) Code Resolution MSC.98(73). For drilling units, specific reference should be made to the requirements of the 2009 IMO MODU Code Resolution A.1023(26) Ch 9.

(a) When the emergency fire pump is electrically driven, the power is to be supplied by a source other than that supplying the main fire pumps. This source is to be located outside the machinery spaces containing the main fire pumps and their source of power and drive units, *see also* Pt 6, Ch 2,3.1.5(b)(iv).
(b) The cables to the emergency fire pump are not to pass through the machinery spaces containing the main fire pumps and their source of power and drive units. The cables are to be of a fire-resistant type where they pass through other high fire risk areas.
(c) Where there are electrically driven refrigeration units for carbon dioxide fire-extinguishing systems, one unit is to be supplied by the main source of electrical power and the other unit from the emergency source of electrical power. Exclusive circuits are to be used for the two units, *see also* Pt 6, Ch 2,3.1.5(b)(v).
(d) Each electrically driven carbon dioxide refrigeration unit is to be arranged for automatic operation in the event of loss of the alternative unit.

2.3.6 Fire and gas dampers and ventilation fans serving areas in which fire has been detected and confirmed by group voting are to be shut down automatically. Similar action is to be carried out prior to the release of extinguishing media. Manual shut-down from the main control panel and the fire-control position is also to be available and fire dampers should also be capable of being closed manually from both sides of the bulkhead or deck:

(a) The electrical power required for the control and indication circuits of fire dampers is to be supplied from the emergency source of electrical power.
(b) The control and indication systems for the fire dampers are to be designed on the fail-safe principle, with the release system having a manual reset.

2.3.7 The electrical power for the control, indication and alarm circuits of fire doors is to be supplied from the emergency source of electrical power. The control and indication systems for the fire doors are to be designed on the fail-safe principle, with the release system having a manual reset.

2.3.8 Automatic sprinkler systems are to be considered as part of the fire detection system.

2.3.9 Whenever any sprinkler comes into operation, an alarm and visual indication is to be initiated on the panels and repeaters required by 2.3.2.

2.3.10 The main fire and gas panel and the fire control point repeater, if fitted, are to indicate the location and zone/section of the sprinklers that have been initiated and the status of the system, as follows:

(a) Low level and pressure in the standing fresh water pressure tank.
(b) Start-up of the electrically driven pump which is brought into action automatically by the pressure drop in the system, before the standing fresh water charge in the pressure tank is completely exhausted.
(c) The status of the electrically driven or diesel driven sea-water fire pumps that are required to start up when the fresh water system is exhausted.

2.3.11 The design of the sprinkler systems is to be in accordance with SOLAS Ch II-2 Reg 10 and IMO Fire Fighting System (FSS) Code Resolution MSC.98(73) Ch 8. The automatic alarm and detection system is to be fed by exclusive feeders from two sources of electrical power, one of which is to be an emergency source, with automatic changeover facilities located in, or adjacent to, the main alarm and detection panel.

2.4 Fire safety stops

2.4.1 Means of stopping all ventilating fans with manual reset are to be provided, outside the spaces being served, at positions which will not readily be cut off in the event of a fire. The provisions for machinery spaces are to be independent of those for other spaces.

2.4.2 Machines driving forced and induced draught fans, and independently driven oil pumps for fuel, lubricating, hydraulic or stored oil are to be fitted with remote controls, with manual reset, situated outside the space concerned so that they may be stopped in the event of fire arising in the space in which they are located.

2.4.3 Means of cutting off power to the galley, in the event of a fire, are to be provided outside the galley exits, at positions which will not readily be rendered inaccessible by such a fire.

2.4.4 Fire safety stop systems are to be designed on the fail-safe principle or, alternatively, the power supplies to, and the circuits of, the fire safety stop systems are to be continuously monitored and an alarm initiated in the event of a fault. Power supply circuits are to be duplicated and arranged in compliance with Pt 6, Ch 2,5.2.1 of the Rules for Ships. Cables are to be of a fire-resistant type, *see* Pt 6, Ch 2,11.5.3 of the Rules for Ships.

2.5 Additional requirements for accommodation fire detection systems

2.5.1 The requirements for accommodation fire detection systems are given in Pt 6, Ch 2,17 of the Rules for Ships, which are to be complied with where applicable.

2.5.2 Fire detection systems for crew accommodation spaces and accommodation spaces for offshore personnel as defined in Pt 1, Ch 2,2 of these Rules, and for accommodation and support units, are also to comply with the additional requirements given below.

2.5.3 Where the fire detection system does not include means of remotely identifying each detector individually, a minimum of two zones/sections of detectors are to serve cabin spaces and are to be arranged one on each side of the unit. Exceptionally, one zone/section of detectors may be permitted to serve both sides of the unit and more than one deck where it is satisfactorily shown that the protection of the unit against fire will not be reduced thereby.

2.5.4 Heat detectors used for the protection of accommodation spaces are to operate before the temperature exceeds 78°C but not until the temperature exceeds 54°C.

2.5.5 The permissible temperature of operation of heat detectors may be increased to 30°C above the maximum deckhead temperature in drying rooms and other accommodation spaces having a normally high ambient temperature.

2.5.6 The maximum spacing of detectors in the living quarters is to be in accordance with Table 1.2.1. Other spacing complying with appropriate National Standards will be permitted.

Table 1.2.1

Type of detector	Maximum floor area per detector, in m^2	Maximum distance apart between centres, in metres	Maximum distance away from bulkheads, in metres
Heat	37	9	4,5
Smoke	74	11	5,5

2.6 Machinery space fire detection systems

2.6.1 Where an automatic fire detection system is to be fitted in a machinery space, the requirements of 2.2 and the additional requirements of 2.6.2 to 2.6.5 are to be satisfied. These requirements are also to be applicable for units to be assigned the **UMS** and **CCS** notations, *see* Pt 6, Ch 1.

2.6.2 An audible fire alarm is to be provided, having a characteristic tone which distinguishes it from other audible warnings having lower priority. The audible fire alarm is to be immediately audible at the main control station and at all repeater stations. If the alarm is not accepted within two minutes, a general alarm is to be initiated throughout the unit.

2.6.3 Fire detection control units, indicating panels, detector heads, manual call points and short-circuit isolation units are to be Type Approved in accordance with *Test Specification Number 1* given in LR's *Type Approval System*. For addressable systems, which also require to be Type Approved, *see* Pt 6, Ch 1,2.9.

2.6.4 When it is intended that a particular loop be temporarily switched off locally, this state is to be clearly indicated at the main fire detection control panel. Such actions are to be controlled by a 'permit-to-work' procedure.

2.6.5 It is to be demonstrated to the Surveyor's satisfaction that detector heads are so located that air currents will not render the system ineffective.

■ *Section 3* Systems for broadcasting safety information

3.1 General requirements

3.1.1 This Section states requirements for safety systems which broadcast warning of existing and potential hazards present on the unit and advise personnel on board of necessary actions they need to take.

NOTE
The requirements for the sound pressure levels to be provided by the public address systems and audible alarms should be determined by reference to the International Life-Saving Appliances (LSA) Code and the Code on Alarms and Indicators.

3.1.2 In machinery spaces and other locations with high ambient noise levels, whether continuous or intermittent, audible alarms are to be supplemented by visual alarms.

3.2 Public address system

3.2.1 The requirements for public address systems are given in Pt 6, Ch 2,18.3 of the Rules for Ships, which are to be complied with where applicable.

3.2.2 Additional requirements with respect to unit types as indicated in this Section should also be complied with as applicable.

3.2.3 A public address (PA) system is to be provided which is to be audible in all parts of the unit. The PA microphones are to be located at the main control station and at the fire control station and/or navigating bridge, if fitted. Additional microphones may be provided at other suitable locations, e.g., in the Unit Manager's office.

3.3 General emergency alarm systems

3.3.1 The requirements for general emergency alarm systems are given in Pt 6, Ch 2,18.2 of the Rules for Ships, which are to be complied with where applicable.

3.4 Fire-extinguishing media release alarms

3.4.1 Where it is required that alarms be provided to warn of the release of a fire-extinguishing medium, and these are electrically operated, they are to be provided with an emergency source of electrical power, as required by Pt 6, Ch 2,3.1, and also connected to the main source of electrical power, with automatic changeover facilities located in, or adjacent to, the fire-extinguishing media release panel. Failure of any power supply is to initiate an audible and visual alarm, and the alarm is to be capable of being operated under fire conditions, *see also* Pt 6, Ch 2,1.13 and 1.14.

3.5 Escape route or low location lighting (LLL)

3.5.1 Escape route or low location lighting (LLL), either in the form of electric illumination or photoluminescent strip indicators, is to be provided in accordance with the requirements of SOLAS 1974 as amended, Pt D, Ch II-2, Reg. 13,3.2.5.1. Where satisfied by electric illumination, it is to comply with the requirements of this sub-Section.

3.5.2 The LLL system is to be provided with an emergency source of electrical power as required by Pt 6, Ch 2,3.1 and also connected to the main source of electrical power, with automatic changeover facilities located adjacent to the control panel. For Accommodation Units, the LLL system is to be provided with an emergency source of electrical power as required by Pt 3, Ch 4,4.2 and also connected to the main source of electrical power, with automatic changeover facilities located adjacent to the control panel. The system is to be capable of being operated under fire conditions, *see also* Pt 6, Ch 2,1.14.

3.5.3 The power supply arrangements to the LLL are to be arranged so that a single fault or a fire in any one fire zone or deck does not result in loss of the lighting in any other zone or deck. This requirement may be satisfied by the power supply circuit configuration, use of fire-resistant cables complying with the requirements of Pt 6, Ch 2,11.5.3 of the Rules for Ships, and/or the provision of suitably located power supply units having integral batteries adequately rated to supply the connected LLL for a minimum period of 60 minutes. If the accommodation or part of the accommodation is classified as the Temporary Refuge, the LLL integral batteries are to have a minimum supply capacity of 60 minutes or a period in excess of 60 minutes if the Temporary Refuge is to be rated to maintain integrity for a period in excess of 60 minutes. Where these units are installed within cabins for crew or offshore personnel, or within associated corridors, the batteries are to be of the sealed type, *see* Pt 6, Ch 2,11.2.

3.5.4 The performance and installation of lights and lighting assemblies are to comply with ISO Standard 15370: *Ships and marine technology – Low location lighting on passenger ships*.

■ *Section 4* Emergency lighting

4.1 General requirements

4.1.1 The requirements for emergency lighting are given in Pt 6, Ch 2,18.1 of the Rules for Ships, which are to be complied with where applicable.

■ *Section 5* Protection against gas ingress into safe areas

5.1 General

5.1.1 Heating, ventilation and air conditioning systems serving safe areas are to be provided with alarms and safeguards required by 5.1.2 to 5.1.9 to protect against hazards created by the ingress of gas.

5.1.2 Gas detectors are to be provided in or close to all air intakes serving safe areas. They are to be capable of initiating early warning of the presence of flammable and toxic gases likely to be present on the unit as appropriate to its purpose or service. The detectors are also to be capable of initiating relevant shut-down actions should the concentration of gas increase above the early warning level. To minimise nuisance shut-downs, the provision of duplicated or triple redundant detector heads in each inlet operating in a voting configuration is recommended.

5.1.3 In addition to the detectors required by 5.1.2, exhaust outlets of accommodation modules adjacent to gas hazardous areas may also need to be provided with gas detectors to give warning of ingress of gas when the ventilation system is shut down.

5.1.4 Automatically closed dampers are to be provided in all intakes and exhausts. When the gas detectors required by 5.1.2 and, if fitted, those to which 5.1.3 refers, have detected gas demanding shut-down action, all HVAC inlet and exhaust fans and dampers associated with the point where ingress of gas has been detected are to be shut down and closed in addition to the damper of the duct in which gas has been detected. No reliance is to be placed on solely shutting dampers without also shutting down the associated fan motors. Dampers utilised to mitigate against the ingress of gas are to be suitably rated for this service.

5.1.5 A five-second retention time between air inlet gas detectors and downstream dampers is to be considered in the ducting design for machinery space ventilation.

5.1.6 Where a machinery space is not served by redundant air intake ducts, consideration should be given to the provision of gas detection within the space. Consideration should also be given to the isolation of electrical equipment, other than that suitable for installation within a Zone 1 location, *see* Ch 2,8.1.6, when flammable gas is detected within the space.

5.1.7 The alarms for loss of ventilation, and loss of over pressure required by Ch 2,4 may be incorporated into the fire and gas central panel.

5.1.8 Consideration is to be given to the provision of gas detection within emergency generator spaces and their switchboard spaces as well as in the ventilation system intakes. In the event of gas being detected in the air intakes, the ventilation system intake and exhaust fan dampers are to be shut down and associated fan motors are to be stopped. The emergency generator may continue to run, provided that aspiration air is drawn separately from outside the space and the engine induction and exhaust arrangements comply with the relevant requirements of Ch 2,7. However, if gas is detected within the spaces, the generator is to be shut down.

5.1.9 Diesel driven fire pumps will not be required to be shut down if gas is detected in the area or space in which they are sited, provided that no electrical equipment, other than that suitable for installation in a Zone 1 location, *see* Ch 2, 8.1.8, is required to remain in operation. Many fire-water pump drives (i.e., diesel drive units, etc.) are not certified and are therefore not rated to operate in a hazardous atmosphere. Therefore they are to be suitably protected by other means, as follows:

- housed in a safe area, within a suitably rated enclosure with fire rated and gastight barriers, designed to run with the firewater pump drive enclosure shut down (i.e., enclosure fire and gas dampers closed, etc.);
- diesel drives are to be provided with engine overspeed protection, etc.

This is to mitigate against gas ingress and enable such drives to continue to operate. However, they should not be started up with gas present, and any electrical starting circuits, and control and alarm circuits, not suitable for operation in a Zone 1 location are also to be isolated.

■ *Section 6*
Protection against gas escape in enclosed and semi-enclosed hazardous areas

6.1 General

6.1.1 Enclosed and semi-enclosed hazardous areas as defined in Ch 2,1.2 are to be provided with alarms and safe guards required by 6.1.2 to 6.1.4 to give protection against accidental release of hydrocarbon and toxic gases.

6.1.2 Gas detectors are to be provided to give warning of gas release in the following locations:

- Drill floor.
- Mudrooms.
- Shale shaker space.
- Wellhead and riser areas.
- Adjacent to process equipment.
- Machinery rooms with gas-fuelled equipment.
- Any other location where there is a significant risk of a leakage of gas or of liquid liable to release flammable vapour.

6.1.3 Detectors are to be capable of initiating early warning of the presence of gas and are also to be capable of initiating relevant shut-down actions via the emergency shut-down system called for in Section 7 when higher gas concentrations are detected. To minimise nuisance shut-downs, it is recommended that trips be initiated by confirmed response by more than one detector within the space concerned or the provision of similar voting arrangements.

6.1.4 Gas turbines and their enclosures shall be fitted with flammable gas detectors at the following locations:

- Turbine air intakes.
- Ventilation system air intakes.
- Ventilation system exhausts.

The presence of gas in the turbine air intake and/or ventilation system air intake is to initiate shut-down of the turbine and the ventilation system. If gas is sensed only in the ventilation exhaust, the ventilation system is to continue running and the turbine is to be shut down. Proposals involving shutting down and inerting the turbine machinery enclosure for the conditions described will be given special consideration.

6.1.5 If an enclosed hazardous area is supplied with a ventilation system, the presence of gas in the enclosed hazardous area and/or the ventilation system air extracts from this area is not to initiate the shut-down of the area's ventilation system as this will result in the build-up of hazardous gas in this area. However, other suitable shut-down functionality (i.e., tripping of electrical equipment within the area, process plant shut-down and emergency depressurisation, etc.), is to be initiated, dependent upon the degree of hazard.

Section 7 Emergency shut-down (ESD) systems

7.1 General

7.1.1 An ESD system is to be provided when any process presents a hazard which could affect the safety of personnel, the overall safety of the unit or the pollution of the environment. The system is to satisfy the requirements of 7.1.2 to 7.1.17.

7.1.2 The ESD system is to operate in association with those items of plant defined in Pt 6, Ch 1,1.2.3 as applicable, and is to incorporate levels of shut-down appropriate to the degree of hazard to personnel, the unit and the environment. The arrangements are to be derived using hazard analysis techniques.

7.1.3 The operation of the ESD system is to be initiated manually. In addition, operation is also to be initiated automatically by signals derived from the fire and gas detection system and signals derived from process and other equipment sensors. The shut-down of drilling equipment, required to make the installation safe, is only to be initiated manually.

7.1.4 Manual ESD actuation points for complete shut-down of the installation are to be provided at the main control station and other suitable locations, e.g., at the helicopter deck, and the emergency evacuation stations.

7.1.5 Each manual ESD actuation point on the installation is to be clearly identified, at field location, as well as with identifiable Tag and Location on Operator Control Screen.

7.1.6 The ESD system is to be arranged with automatic changeover to a standby power supply, ensuring uninterrupted operation of the system in the event of failure of the normal power supply.

7.1.7 Failure of any power supply to the ESD system is to initiate an audible and visual alarm.

7.1.8 The characteristics of the failure to safety operation for plant and equipment is the automatic reversion to the least hazardous condition upon failure of protective system, logic, sensors, actuators or power source.

Note

This requirement is normally realised by employing a de-energise to trip design. Special consideration is given to sub-sea christmas tree solenoid valves which are not normally energised.

7.1.9 Hydrocarbon related components are to be equipped with at least two independent levels of safety protection to prevent or minimise the effects of an equipment failure within the process. Where provision of two diverse means of protection cannot be achieved, special consideration must be given to the design of the alternative means.

7.1.10 High level ESD (as defined in accordance with 7.1.2, e.g., platform shut-down, production shut-down) is to be provided with local reset of each final element. Elements affected by low level ESD (as defined in accordance with 7.1.2, e.g., unit shut-down) may be reset by means of a remote manual group reset operation from the central control room.

7.1.11 Software input inhibits and output overrides may be used for maintenance purposes. However, this method of applying inhibits and overrides must be restricted to some of the fire and gas systems and low level of shut-down functions only. Physical key switches are to be used for applying inhibits and overrides for high level, safety critical shut-down system.

7.1.12 Start-up overrides may be applicable to low level and similar trips during plant start-up. These overrides are to be cancelled automatically once the normal process condition has been reached or when a fixed period of time has expired.

7.1.13 Where arrangements are provided for overriding parts of an ESD system, they should be such that inadvertent operation is prevented. Visual indication is to be given at the main control point when an override is operated.

7.1.14 Accumulators for pneumatic and hydraulic systems are to have sufficient capacity to allow the performance of one complete shut-down followed by reset and a further shut-down, without the need for recharging the accumulator.

7.1.15 Where ESD applications are to be implemented by programmable electronic instruments, a qualitative risk-based approach to the specification and design of these systems is to be adopted. The ESD system is to comply with the requirements of IEC 61508 – *Functional safety of electrical/electronic safety-related systems* and, as far as applicable, those of IEC 61511 – *Functional safety – safety instrumented systems for the process industry sector*. Each measure to control or mitigate hazards is to be assigned an appropriate degree of risk reduction which contributes to the overall risk reduction. The risk reduction figure is to be translated into performance standards for each measure which will be specified in terms of functionality, safety integrity and survivability, *see also* Pt 6, Ch 1, 2.9 to 2.11.

Note

The implementation of a programmable electronic system (P.E.S.) to perform high safety integrity level functions is not recommended unless the P.E.S. has been certified by the supplier or external body to meet the requirements of IEC 61508 2010 in terms of the safety integrity level (SIL) PFD_{AVG} requirements.

7.1.16 Status, diagnostic and alarm information exchange executed by read-only soft links to remote digital systems for display purposes may be provided, as applicable, in addition to a matrix panel, *see* Pt 6, Ch 1,2.13.9 of the Rules for Ships.

7.1.17 Consideration is to be given to the segregation of cabling and wiring associated with high level ESD functions from that associated with other functions.

7.2 Electrical equipment

7.2.1 Equipment which is located in spaces other than enclosed spaces and which is capable of operation after emergency shut-down should be suitable for installation in zone 1 locations. Such equipment which is located in enclosed spaces should be suitable for its intended application, *see also* Ch 2,8.1.6 and 8.1.8. At least the following facilities are to be operable after an emergency shut-down:
- emergency lighting detailed in Pt 6, Ch 2,3.1.5 for half an hour;
- blow out preventer control system;
- general alarm system;
- public address system; and
- battery-supplied radiocommunication installations.

It is noted that guidance from the IMO MODU Code and IEC 61892-7 for MODUs details the suitability of zone 2 certified equipment for facilities that are required to function following an emergency shut-down and provide continued operation during an ongoing emergency. However, LR recommends the utilisation of zone 1 certified equipment for facilities that are required to function following an emergency shut-down and provide continued operation during an ongoing emergency. This will ensure consistency with IEC 61892-7 for offshore production units and other guidance regarding offshore hydrocarbon production installations

■ *Section 8* Riser systems

8.1 General

8.1.1 The provisions laid down in Pt 3, Ch 12 for the assignment of the special features class notation **PRS** are to be complied with.

8.1.2 The location where the riser(s) is situated, inboard of the unit, is to be safeguarded by an appropriate fire and gas detection system complying with the requirements of Section 2. In the event that a fire or confirmed gas leakage is detected, effective automatic means of closing down the riser(s) are to be provided.

8.1.3 The riser system is to be equipped with an emergency shut-down valve, fitted as close to the waterline as possible. The valve is to be of the self-actuating type with its own localised control medium and interfaces with the installation ESD, as specified in Section 7.

8.1.4 Automatic testing facilities which periodically actuate the inboard riser valves are to be provided.

8.1.5 The riser system is to be provided with means of leakage monitoring and means to ensure integrity of the riser system. The leak detection system is to take the following parameters into consideration:
- Continuous mass balance.
- Continuous volumetric balance corrected for temperature and pressure.
- Continuous monitoring of rate of change of pressure.
- Continuous monitoring of rate of change of flow.
- Low pressure alarms.
- Low flow alarms.
- Reverse flow alarm.

8.1.6 Control of the riser system is to be effected from a clearly defined control centre, provided with sufficient instrumentation to indicate the conditions at each end of the riser system and to ensure effective control, shut-down and disconnection.

8.1.7 Where more than one control centre is provided, the arrangements are to be such that only one control centre can start up the riser system at a given time. Clear indication is to be provided to show which centre is in control.

8.1.8 Independent means of voice communication are to be provided between the single point mooring end of the riser system and the control centre(s).

8.1.9 Alarms displayed in a control centre are to be audible and visual. An alarm event recorder is to be provided.

8.1.10 The riser system is required to be safely disconnected when the design limits are exceeded. Self-closing devices positioned as close to the rapid disconnecting point as possible are to be fitted so as to ensure accidental spillage at the junction is minimised. A suitable alarm is to be provided, warning that the design limits have been reached.

■ *Section 9* Protection against flooding

9.1 General requirements

9.1.1 The requirements for watertight and weathertight integrity and the general requirements regarding the control and closure of watertight and weathertight doors and hatch covers in order to satisfy the intact and damaged stability criteria are given in Pt 4, Ch 7, to which reference should be made.

9.1.2 A system of alarm displays and controls is to be provided which will ensure satisfactory supervision and control of watertight doors and hatch covers, and also in the case of column-stabilised units to give warning of ingress of water.

9.1.3 For column-stabilised units, the alarm displays and controls are to be provided at a centralised panel at the ballast control station. *See* Pt 4, Ch 7,3, Pt 5, Ch 13,8.6 and Pt 6, Ch 1,2.8.

9.1.4 For surface type and self-elevating units, the alarm displays and controls are to be provided at a centralised panel either at the ballast control station, the main control station, the bridge, or at the conning position, as applicable, *see* Pt 4, Ch 7,3.

9.1.5 Doors and hatch covers needed to ensure watertight integrity of internal openings and which are used during operation of the unit while afloat are to be remotely controlled. Detailed alarm, indication, and control requirements are given in 9.2 for electrically operated watertight doors and hatch covers, and in 9.3 for hydraulically operated watertight doors and hatch covers.

9.1.6 Doors and hatch covers needed to ensure watertight integrity of internal openings which are normally kept closed when the unit is afloat are to be provided with alarm indicators in accordance with 9.4.

9.1.7 Doors and hatch covers needed to ensure watertight and weathertight integrity of external openings are to comply with 9.1.4 and 9.1.6, as appropriate, in accordance with the requirements of Pt 4, Ch 7.

9.1.8 When other types of closing appliances (e.g., on ventilators) are required to be remotely controlled or alarmed in accordance with the requirements of Pt 4, Ch 7, the general requirements of this Section are to be complied with, as applicable.

9.1.9 Bilge level sensors and water level indication required for column-stabilised units are to be in accordance with 9.5.

9.2 Electrically operated watertight doors and hatches

9.2.1 The requirements for electrically operated watertight doors and hatches are given in Pt 6, Ch 2,19.1 of the Rules for Ships, which are to be complied with where applicable.

9.2.2 Where watertight doors and hatch covers are to be operated electrically, the term ‘door’ is to be understood to include hatch covers.

9.2.3 Where the Rules for Ships refer to ‘bulkhead deck’ this should be substituted for ‘final water plane after damage’.

9.2.4 The ‘master-mode’ switch is to be Type Approved in accordance with *Test Specification Number 1* given in LR’s *Type Approval Scheme*.

9.3 Hydraulically operated watertight doors and hatch covers

9.3.1 Where watertight doors and hatch covers are operated hydraulically, the arrangements are to be equivalent to 9.2.1 and 9.2.5 for electrically operated doors and hatch covers.

9.3.2 Electrical indication arrangements for hydraulically operated doors and hatch covers are to meet the requirements of 9.2.1 and 9.2.5.

9.3.3 Where four or more doors or hatch covers are powered from a single hydraulic power unit, duplicated hydraulic pump units are to be provided.

9.4 Indicators for doors, hatch covers and other closing appliances

9.4.1 The indicator system(s) of 9.1.5 and 9.1.6 is to be designed on the fail-safe principle, such that, in the event of a fault, the system cannot incorrectly indicate that a door, hatch cover, or other closing appliance is fully closed. A green light is to indicate when a door, hatch cover or closing appliance is closed and a red light is to indicate that it is not fully closed or secured.

9.4.2 The electrical power supply for the indicator system(s) is to be independent of any electrical power supply for operating and securing the doors and hatch covers.

9.5 Bilge level and flood water level alarm and indication

9.5.1 Column-stabilised units are to be provided with arrangements to warn of high bilge level and ingress of water due to flooding, in accordance with 9.5.2 to 9.5.4, *see also* Pt 5, Ch 13,8.6.

9.5.2 Bilge high level alarms and water high level alarms are to be provided on a centralised control panel situated in the ballast control room required by Pt 6, Ch 1,2.8.

9.5.3 Bilge high level or water high level alarm sensors are to be installed in all compartments which are large enough to affect stability and which are required to remain watertight to comply with the intact and damaged stability criteria. Tanks fitted with remote tank level indicators with displays other than in the ballast control room are exempt from this requirement. The requirements for chain lockers are to comply with Pt 5, Ch 13,8.6.3.

9.5.4 Pump-rooms and propulsion rooms in lower hulls and columns are to be provided with two level sensors in each compartment, one for detection of high bilge water level, and a second detector to warn of flooding.

Section

■ *Section 1* Hazardous areas – General

1.1 Application

1.1.1 Units for oil and gas exploration, units with production and process plant, drilling plant and other units where explosive gas-air mixtures are likely to be present are to be classified into 'hazardous areas' and 'non-hazardous areas' in accordance with the requirements of this Chapter, or alternatively, with an acceptable Code or Standard giving equivalent safety.

1.1.2 These requirements do not apply to the release of explosive gas-air mixtures as a consequence of an uncontrolled well blow out or catastrophic failure of pipes or vessels.

1.1.3 For special requirements relating to drilling, workover and wirelining operations, *see* Section 3.

1.1.4 For special requirements relating to units intended for the storage of oil in bulk, liquefied gases or other hazardous liquids, *see* Sections 9 to 11.

1.1.5 The hazardous areas applicable to well testing will be specially considered.

1.2 Definitions and categories

1.2.1 A hazardous area is an area on the unit where flammable gas-air mixtures are, or are likely to be, present in sufficient quantities and for sufficient periods of time such as to require special precautions to be taken in the selection, installation and use of machinery and electrical equipment.

1.2.2 Hazardous areas may be divided into Zones 0, 1 and 2, defined as follows:

Zone 0: An area in which an explosive gas-air mixture is continuously present or present for long periods.

Zone 1: An area in which an explosive gas-air mixture is likely to occur under normal operating conditions.

Zone 2: An area in which an explosive gas-air mixture is unlikely to occur, and if it does occur, it will only persist for short period.

Non-hazardous areas are those which are not classified as hazardous according to the above definitions.

1.2.3 An enclosed space is considered to be any building, room or enclosure, e.g., cabinet, within which, in the absence of artificial ventilation, the air movement will be limited and any flammable atmosphere will not be dispersed naturally.

1.2.4 A semi-enclosed space is considered to be a space which is adjoining an open area, where the natural ventilation conditions within the space are restricted by structures such as decks, bulkheads or windbreaks in such a manner that they are significantly different from those appertaining to the open deck, and where dispersion of gas may be impeded.

1.2.5 When an enclosed or semi-enclosed space is provided with a mechanical ventilation system which ensures at least 12 air changes per hour and no pockets of stagnant air within the space, such a space may be regarded as an open space.

1.2.6 An open-air area is one without stagnant regions where vapours are rapidly dispersed by wind and natural convection. Typically, air velocities will rarely be less than 0,5 metres per second and will frequently be above 2 metres per second.

1.2.7 Under normal operating conditions, a hazardous zone or space may arise from the presence of any of the following:

(a) Spaces or tanks containing any of the following:
   (i) Flammable liquid having a flash point not exceeding 60°C closed-cup test;
   (ii) Flammable liquid having a flash point above 60°C closed-cup test, heated or raised by ambient conditions to a temperature within 15°C of its flash point;
   (iii) Flammable gas.
(b) Piping systems or equipment containing fluid defined by (a) and having flanged joints, glands or other fittings through which leakage of fluid may occur.
(c) Piping systems or equipment containing flammable liquid not defined by (a), and having flanged joints, glands or other fittings through which leakage of fluid in the form of a fine spray or mist could occur.

(d) Equipment associated with processes such as battery charging or electrochlorination which generate flammable gas as a by-product, and having vents or other openings from which gas may be released.

1.2.8 Release of explosive gas-air mixtures may be categorised into continuous, primary and secondary grades.

(a) Continuous grades of release include the following:
   (i) The surface of a flammable liquid in a closed tank or pipe.
   (ii) A vent or other opening which releases flammable gases or vapours frequently, continuously or for long periods.
(b) Primary grades of release include the following:
   (i) Pumps and compressors with standard seals, and valves, flanges and fittings containing flammable fluids if release of fluid to atmosphere during normal operation may be expected.
   (ii) Sample points and process equipment drains which may release flammable fluid to atmosphere during normal operation.
   (iii) Pig launcher and receiver doors which are opened frequently.
   (iv) Vents which frequently release small quantities, or occasionally release larger quantities, of flammable gases to atmosphere.
   (v) Tanks or openings of the active mud circulating system between the well and the final degasser discharge which may release gas during normal operation.
   (vi) Drilling operations in enclosed or semi-enclosed spaces, *see* Section 3.
(c) Secondary grades of release include the following:
   (i) Pumps and compressors, and valves, flanges and fittings containing flammable fluids.
   (ii) Vents which release flammable gases intermittently to atmosphere.
   (iii) Tanks or openings of the mud circulating system from the final degasser discharge to the mud pump connection at the mud pit.
   (iv) Drilling, workover and wirelining operations in open spaces, *see* Section 3.

1.2.9 Gases and vapours are considered lighter than air when their density, on release to atmosphere, is less than approximately 0,75 relative to the ambient air.

1.3 Plans

1.3.1 Single copies, unless otherwise stated, of the following plans and particulars on 'hazardous areas' are to be submitted for consideration:

- Hazardous area classification philosophy.
- Hazardous area classification design specifications.
- Facility layout plans (plot plans).
- Hazardous area classification schedule (data sheets), *see also* 1.3.2.
- Hazardous area classification plans.

1.3.2 It is expected that the data sheets, referred to in 1.3.1, include, but are not limited to, the following information:

- Equipment identification.
- Operating conditions.
- Media and media properties.
- Fluid category.
- Sources of potential release.
- Grades of release.
- Venting rates.
- Hazardous zones determined.
- Dimension of each hazardous zone.
- Code or Standard used for reference.

1.3.3 Single copies, unless otherwise stated, of the following plans and particulars on 'ventilation' are to be submitted for consideration:

- Ventilation design philosophy.
- Ventilation design specifications.
- Ventilation layout plans.
- Ducting and instrumentation plans (D & ID's).

■ *Section 2* Classification of hazardous areas

2.1 General

2.1.1 The hazardous areas as specified may be extended or restricted depending on conditions such as fluid system pressure and composition, or by the use of structural arrangements such as fire walls, windshields, special ventilation arrangements, etc. Special requirements may be applicable to units intended for the storage in bulk of flammable liquids or gases, *see* Sections 9 to 11.

2.1.2 Relatively small non-hazardous areas surrounded by or confined by hazardous areas, or Zone 2 areas within Zone 1 areas, are to be classified as the adjacent surrounding hazardous area.

2.1.3 For gas disposal systems other than permanently ignited flares, and for vents for large quantities of hydrocarbon gas from production facilities, the classification and extent of the surrounding hazardous areas should be based on dispersion calculations.

2.1.4 For permanently ignited flares, consideration is to be given to possible 'flame out' condition or intentional periods of cold venting and the hazardous area created by such are to be determined.

2.1.5 Within these Rules, all reference to the extent of the hazardous zones given as a radius refers to the horizontal extent of the zone, except where specifically stated as being a spherical zone; for vertical extent of zones, *see* 2.5.

2.2 Zone 0

2.2.1 Areas to be classified as Zone 0 include:

(a) the internal space of a closed tank or pipe containing a flammable liquid or gas, crude oil or active mud, or a space where an oil-gas-air mixture is continuously present, or present for long periods;
(b) unventilated spaces, containing a source of release (i.e., flange, valve, etc.), separated by a single gastight bulkhead, or deck, from a tank containing flammable liquid or gas;
(c) a region within 3 m radius from non-pressurised tank vents or other sources, or within 15 m radius from cold vents where discharge rates exceed 10 m^3/h, which releases flammable gases or vapours frequently, continuously or for long periods.

2.3 Zone 1

2.3.1 Areas to be classified as Zone 1 include:

(a) adequately ventilated closed or semi-enclosed spaces containing primary grades of release, *see* 1.2.8(b);
(b) mechanically ventilated closed spaces, containing a source of release (i.e., flange, valve, etc.) separated by a single gastight bulkhead or deck from a tank containing flammable liquid or gas. Or unventilated closed spaces, not containing any sources of release, separated by a single gastight bulkhead, or deck, from a tank containing flammable liquid or gas;
(c) in open spaces, the area surrounding a primary grade of release. The extent of the Zone 1 hazardous area will be based upon the primary grade source of release;
(d) in open spaces, the area within 3 m from pig launcher and receiver doors. This may be reduced to 1,5 m if the equipment is purged with nitrogen or water washed before opening;
(e) in open spaces, the area local to any opening associated with an enclosed Zone 1 area, any ventilation outlet from a Zone 1 space, or any access, such as a doorway or non-bolted hatch to an enclosed Zone 1 hazardous area, is to be classified as a Zone 1 space. The extent of the external Zone 1 hazardous area will be based upon the largest source of release with the enclosed Zone 1 area;
(f) semi-enclosed spaces, such as inadequately ventilated pits, ducts or similar structures situated in locations which would otherwise be a Zone 2, but where their arrangement is such that gas dispersion cannot easily occur;
(g) for drilling units, specific reference is to be made to the requirements, given in the 2009 IMO MODU Code Resolution A.1023(26) Ch 6, regarding the extent of Zone 1 hazardous areas on MODUs, as well as the following Section 3; and
(h) for tanker storage facilities containing flammable liquids or flammable liquefied gases, specific reference is to be made to the requirements, given in IEC 60092-502, regarding the extent of Zone 1 hazardous areas on the MOU.

2.4 Zone 2

2.4.1 Areas to be classified as Zone 2 include:

(a) adequately ventilated closed or semi-enclosed spaces containing secondary grades of release, *see* 1.2.8(c);
(b) in open spaces, the area beyond the Zone 1 specified in 2.3.1(c) and (d), and beyond the semi-enclosed space specified in 2.3.1(f). The extent of the Zone 2 hazardous area will be based upon the primary grade source of release;
(c) in open spaces, the area surrounding secondary grades of release, any ventilation outlet from a Zone 2 space or any access to a Zone 2 space. The extent of the Zone 2 hazardous area will be based upon the source of release;
(d) mechanically ventilated closed spaces not containing a source of release separated by a single gastight bulkhead or deck from a tank containing flammable liquid or gas;
(e) for drilling units, specific reference is to be made to the requirements, given in the 2009 IMO MODU Code Resolution A.1023(26) Ch 6, regarding the extent of Zone 2 hazardous areas on MODUs as well as the following Section 3;
(f) For tanker storage facilities containing flammable liquids or flammable liquefied gases, specific reference is to be made to the requirements given in IEC 60092-502 regarding the extent of Zone 2 hazardous areas on the MOU;
(g) the area within a 3 m radius from bunds or barriers intended to contain spillage of liquids defined by 1.2.7(a); and
(h) air-locks between a Zone 1 and a non-hazardous area, *see* 4.1.3(c).

2.5 Vertical extent of hazardous zones

2.5.1 The relationship between the hazard radius and the full 3-dimensional envelope of the hazardous area is dependent upon the height and orientation of the release, and the hazard radius. If the release height and the generated hazardous radius zone are greater than 1 m above the deck, then the developed hazardous area is independent of potential hazardous accumulations of flammable releases at deck level. If the release height and the generated hazard radius are less than 1 m above the deck, then the developed hazardous area is dependent on potential hazardous accumulations of flammable releases at deck level and the subsequent hazardous area needs to take into account the generated hazardous area at deck level.

2.5.2 For tanker storage facilities containing flammable liquids or flammable liquefied gases, specific reference is to be made to the requirements given in IEC 60092-502 regarding the extent of Zone 1 and Zone 2 hazardous areas on the MOU.

Section 3
Hazardous areas – Drilling, workover and wirelining operations

3.1 General

3.1.1 This hazardous area classification applies to any part of the drilling derrick or equipment which could potentially release oil or gas from the well, including equipment that is required to operate under controlled emergency conditions such as during a blow out.

3.1.2 The requirements of Section 2 are also to be complied with, where applicable.

3.2 Classification

3.2.1 For MOU drilling units, specific reference is to be made to the requirements given in the 2009 IMO MODU Code Resolution A.1023(26) Ch 6 regarding the extent of hazardous areas on MODUs. However, it must be recognised that other recognised Standards (i.e., IP15, etc.) give additional and potentially different hazardous area guidance associated with drill rigs and facilities. As such, the guidance given in these alternative Standards may be more applicable to the drilling facilities associated with the MOU to be classified.

Section 4
Enclosed and semi-enclosed spaces with access to a hazardous area

4.1 General

4.1.1 As far as practicable, access doors or other openings should not be provided between a non-hazardous space and a hazardous area or space, or between a Zone 2 space and a Zone 1 space.

4.1.2 Where such openings are necessary, an enclosed or semi-enclosed space with a direct access door or opening leading to an area or space which is of a greater hazard classification is to be regarded as the same hazard classification as the area or space into which this door or opening leads, except where suitable arrangements as permitted by 4.1.3 are provided.

4.1.3 An enclosed space with direct access to a:

(a) Zone 1 hazardous area may be classified as Zone 2 provided that:
   (i) the access is fitted with a self-closing, gastight door that opens into the Zone 2 space; and
   (ii) ventilation is such that the air flow with the door open is from the enclosed space to the Zone 1 hazardous area; and
   (iii) loss of ventilation is alarmed at a manned control station.

(b) Zone 2 hazardous area may be classified as non-hazardous provided that:
   (i) the access is fitted with a self-closing, gastight door that opens into the non-hazardous space; and
   (ii) ventilation is such that the air flow with the door open is from the non-hazardous space to the Zone 2 hazardous area; and
   (iii) loss of ventilation is alarmed at a manned control station; and
   (iv) the enclosed space is maintained at an overpressure of at least 50 Pa relative to the external hazardous area.

(c) Zone 1 hazardous area may be classified as non-hazardous provided that:
   (i) the access is via an air-lock consisting of two self-closing, gastight doors without any hold-back arrangement, and spaced at least 1,5 m but not more than 2,5 m apart; and
   (ii) the enclosed space is maintained at an over-pressure of at least 50 Pa relative to the external hazardous area; and
   (iii) the relative air pressure within the space is continuously monitored and so arranged that, in the event of loss of overpressure, an alarm is given at a manned control station.

4.1.4 Where one of the doors specified in 4.1.3(c)(i) is required to be weathertight or watertight and the provision of a self-closing mechanism would be impracticable, consideration will be given to waiving the requirement for this door to be self-closing, provided the door is normally kept closed and is provided with a notice to this effect.

Section 5
Machinery in hazardous areas

5.1 General

5.1.1 Installation of mechanical equipment within hazardous areas should be limited to that considered to be necessary for operational purposes within that area. Wherever possible, the installation of fired equipment or internal combustion machinery in hazardous areas should be avoided.

5.1.2 Where it is considered necessary for mechanical equipment or machinery to be installed in a hazardous area, it is to be constructed and installed so as to reduce the risk of sparking due to friction between moving parts or the formation of static electricity, or to ignition due to exposed high-temperature exhausts, etc., *see also* Pt 5, Ch 14,3.13.

5.1.3 Air compressors are not, in general, to be installed in hazardous areas. However, where this is not practicable, such an installation may be accepted provided that the air inlet is from a non-hazardous area in accordance with 6.4, and that the inlet ducting is fitted with suitable gas detectors arranged to give an audible and visual alarm and to shut down the compressor in the event of flammable and/or toxic gases entering the air inlet.

5.1.4 Fans located in hazardous areas are to be of the non-sparking type.

5.1.5 For the requirements appertaining to the installation of suitably protected oil engines in a Zone 2 hazardous area, *see* Section 7.

5.1.6 Wherever possible, piping system arrangements are to preclude direct communication between hazardous and non-hazardous areas, and between hazardous areas of different classifications. Where pipes, ducts or cables pass through decks or bulkheads, the penetration shall be designed to prevent the passage of hazardous gases.

5.1.7 Maintenance hatches and removable panels are to be provided with suitable seals to prevent the passage of hazardous gases when closed.

5.1.8 When oil storage pumps and ballast pumps in dangerous or hazardous spaces are fitted with automatic or remote controls so that under normal operating conditions they do not require any manual intervention by the operators, they are to be provided with the alarms and safety arrangements required by Table 2.5.1 as appropriate. Alternative arrangements which provide equivalent safeguards will be considered. The design of the alarm, control and safety systems is to comply with the requirements of Pt 6, Ch 1,2. Where machinery is arranged to start automatically or from a remote control station, interlocks are to be provided to prevent start-up under conditions which could cause hazard.

Table 2.5.1 Alarm and safety arrangements

Item	Alarm	Note
Bulkhead gland temperature	High	Any machinery item
Bearing temperature	High	Any machinery item
Pump casing temperature	High	'Oil storage' pumps only
Bilge level	High	
Hydrocarbon concentration	High	>10% LEL

■ *Section 6* **Ventilation**

6.1 General requirements

6.1.1 Mechanical ventilation systems are to be capable of continuous operation by the provision of adequate standby/redundancy capable of maintaining the required flow rates and pressure differentials. Machinery spaces are, where practicable, to be served by redundant air intake ducts.

6.1.2 Open or semi-enclosed spaces which are designed to be ventilated by natural means are to achieve a minimum of 12 air changes per hour for 95 per cent of the time. This natural ventilation may be augmented by mechanical means.

6.1.3 Non-hazardous enclosed spaces are to be maintained with an overpressure of at least 50 Pa in relation to any adjacent more hazardous areas or spaces. The non-hazardous area ventilation with positive pressurisation is to be designed to help mitigate against potential gas ingress to the non-hazardous area, so that where there is any doorway, hatch or other opening in the contiguous boundary, the ventilation helps to prevent the transmission of fluids from the more hazardous area or space to the less hazardous space.

6.1.4 Accommodation spaces are to be maintained at a positive pressure in relation to the outside atmosphere.

6.1.5 Ventilation services to drilling utilities areas and to well-head areas should, where practicable, be separate from services to other hazardous areas.

6.1.6 Air supplied for combustion and/or cooling of engines or other fuel-burning equipment is to be supplied separately from general ventilation services. The ventilation system for engine or boiler rooms is to be independent of all other ventilation systems. Induced draught fans or a closed system of forced draught may be employed for fired equipment, or the fired equipment may be enclosed in a pressurised air casing.

6.1.7 System design is to be arranged for individual isolation to enable continuity of operation and purging of spaces following contamination.

6.1.8 The system design is to take into account the possible weathervaning of the unit and periods when the current is the prevailing factor, such that the air intake, at low wind speeds, may be partially starved of air.

6.1.9 Ducting materials, including associating fittings, are to be of a non-combustible material, to be of all welded construction adequate to withstand likely damage and corrosion and to be suitable for a marine saline atmosphere. Ventilation fans are to have non-overloading, non-stall characteristics and are to be fitted with anti-sparking tracks.

6.1.10 For aspects of ventilation systems relating to fire integrity, *see* Chapter 3, and for gas detection requirements, *see* Ch 1,5.

6.2 Ventilation of hazardous spaces

6.2.1 Ventilation systems and ducting for spaces designated as hazardous areas are to be entirely separate from ventilation systems and ducting for spaces designated as non-hazardous areas.

6.2.2 All enclosed hazardous spaces are to be adequately ventilated by a mechanical ventilation system providing at least 12 air changes per hour. Air change calculations are to be based upon empty volume of space. The mechanical ventilation is to be such that hazardous enclosed spaces are maintained with an underpressure of at least 50 Pa in relation to any adjacent less hazardous areas or spaces.

6.2.3 To ensure that the required relative underpressure is maintained in any hazardous enclosed space, the supply and exhaust fans are to be interlocked so that the supply fan cannot be run unless the exhaust fan is running.

6.2.4 Ventilation arrangements should ensure that the entire space is adequately ventilated, giving an even air distribution, with special consideration to locations where there is equipment which may release gas, and to locations within the space where stagnant pockets of gas could accumulate.

6.2.5 Electric heating elements are to be fitted with automatic temperature control, a high temperature alarm and an independent sensor and cut-out with manual reset. The surface temperature is to be restricted to a maximum of 200°C, or below the ignition temperature of any flammable gas likely to be present in the area.

6.2.6 The presence of gas within the enclosed hazardous area, and/or the ventilation system air extracts from this area, is not to initiate the shut-down of the area's ventilation system as this will result in the build-up of hazardous gas in this area.

6.3 Ventilation of other spaces containing sources of hazard

6.3.1 Ventilation systems and ducting for any space containing a source of release of a flammable substance, but not designated as a hazardous space in its entirety (e.g., by virtue of compliance with 1.2.5), are to be entirely separate from ventilation systems and ducting for other non-hazardous areas or spaces.

6.3.2 The mechanical ventilation is to be such that the space and ducting serving it is maintained at an underpressure of at least 50 Pa in relation to adjacent non-hazardous areas or spaces.

6.3.3 Where the ventilation airflow rate, within the space in relation to the maximum release rate of flammable substances reasonably to be expected under normal operating conditions, is sufficient to prevent any concentration of flammable substances approaching their lower explosive limit, consideration will be given to regarding the entire space, including the zone around equipment contained within it, its ventilation systems and other openings into it, as non-hazardous. Ventilation airflow shall be monitored and appropriate measures taken in the event of failure. For requirements particular to gas turbine rooms and hoods, *see* 6.5.

6.3.4 The presence of gas within the enclosed hazardous area, and/or the ventilation system air extracts from this area, is not to initiate the shut-down of the area's ventilation system as this will result in the build-up of hazardous gas in this area.

6.4 Location of air intakes and exhausts

6.4.1 Supply air intakes are to be located in external non-hazardous areas, at least 3 m from the boundary of any hazardous area.

6.4.2 The siting of supply air intakes should be such as to avoid the possibility of drawing in combustion products from equipment exhausts or hazardous/toxic gases from process equipment.

6.4.3 Ventilation intake and outlet ducts should not pass through spaces of different classification. Where this is unavoidable, ducts may pass through a more hazardous space than the ventilated space, provided such ducts have an overpressure in relation to the space through which they pass. Where necessary, ducts should be of welded, gastight construction. The internal space of such ducts is to have the same zone classification as the ventilated space.

6.4.4 Ventilation outlets are, as far as is practicable, to be located in external areas of the same or lesser zone classification as the ventilated space. Where this is not practicable, appropriate measures are to be taken to prevent backflow into the ventilated space, in the event of ventilation failure.

6.4.5 The separation between air intakes and outlets should be at least 4,5 m. The siting of inlets and outlets should be such as to avoid the possibility of cross-contamination.

6.4.6 Ventilation intakes and outlets are to be located and arranged to avoid ingress of rain, snow and sea-water, even under predicted worst storm conditions.

6.4.7 Gas turbine intakes and exhausts are to be positioned well clear of the unit's structure. Turbine exhausts are to be safely located so as not to endanger personnel or interfere with helicopter operations.

6.5 Gas turbine ventilation

6.5.1 The turbine room is to be designed as a non-hazardous space, mechanically ventilated with at least 12 air changes per hour and arranged so that an overpressure of at least 50 Pa is maintained in relation to the turbine hood.

6.5.2 The turbine hood is to be mechanically ventilated by means of one duty and one 100 per cent standby extraction fan with a ventilation rate adequate to remove heat from the turbine and equipment, and to dilute any flammable gas. Potential leakage from under the turbine hood is to be considered. The ventilation rate is to be at least 12 air changes per hour and arranged so that an underpressure of at least 50 Pa is maintained in relation to the turbine room. On failure of the duty fan an alarm is to be given in the control room and the standby fan automatically activated.

6.5.3 Provided it can be shown that no exposed surface of the turbine or equipment inside the hood will have a surface temperature exceeding 200°C, or that the surface temperature will not exceed 80 per cent of the auto-ignition temperature, expressed in °C, of any flammable gas which may be present, the ventilation rate may be as per 6.5.2 where the turbine is in operation. Under these conditions, the space inside the hood will be classified as a Zone 2 hazardous area.

6.5.4 Where the surface temperature of the turbine or equipment inside the hood could exceed 80 per cent of the auto-ignition temperature of any flammable gas which may be present, the space inside the hood is to be ventilated with at least 90 air changes per hour. Under these conditions, the turbine hood need not be classified as a hazardous area when the turbine is in operation.

6.5.5 The turbine hood ventilation fans referred to in 6.5.2 are to be interlocked with the turbine starting sequence to provide at least five air changes in the turbine hood before start-up of the turbine or the energising of any associated electrical equipment, other than that suitable for installation in a Zone 1 location. On shut-down, the duty fan is to purge the turbine hood until the turbine has stopped. At least one of the fans is to be supplied from an emergency power source.

6.5.6 Equipment which is required to remain activated after shut-down or hood ventilation failure is to be suitable for use in a Zone 1 hazardous area.

6.5.7 Gas detectors are to be installed inside the turbine hood to shut down the turbine on detection of gas.

6.5.8 For gas turbines utilising gas fuel from the production and process facility, the arrangement and capacities of the ventilation system and fuel gas piping are to comply, where applicable, with the requirements of Pt 5, Ch 16, taking into account any additional requirements which may be necessary during start-up or shut-down of the plant.

■ *Section 7*
Oil engines in hazardous areas

7.1 Application

7.1.1 Oil engines are not permitted in Zone 0 and Zone 1 hazardous areas on offshore installations. Oil engines which are required to operate in Zone 2 hazardous areas are to comply with the requirements of 7.1.2 to 7.1.23. National Standards and National Administration Regulations or Codes of Practice which differ from these requirements may also be accepted, provided an equivalent standard of protection is achieved.

7.1.2 The air induction system is to be provided with a shut-off valve located between the engine air inlet filter and the flame arrester. The valve is to be capable of being closed manually. The valve is also to be capable of being automatically closed by the engine overspeed device and it is recommended that the induction air valve and engine fuel supply should automatically close by a signal from a local gas sensor.

7.1.3 An approved corrosion resistant flame arrester constructed and tested to a recognised Standard is to be provided in the induction system. The flame arrester is to be as close to the engine as possible with good access for inspection and overhaul.

7.1.4 Joints used in the induction and exhaust systems are to be designated either as 'open joints' or 'closed joints'.

7.1.5 An open joint will allow the free passage of gas but will not allow the passage of flame. The dimensions of such a joint are to be determined in accordance with Fig. 2.7.1. A flame arrester is a particular type of open joint considered separately by testing.

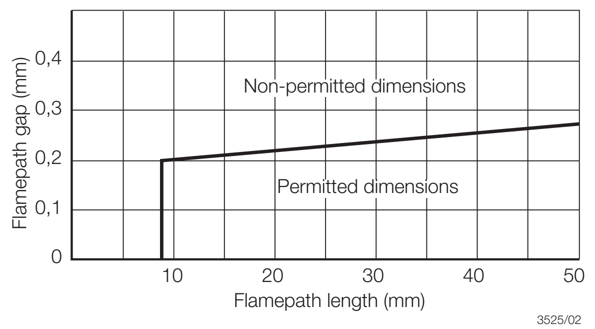

Fig. 2.7.1
Relationship between length and gap for flamepaths

7.1.6 A closed joint will not allow the passage of either gas or flame under normal or test conditions.

7.1.7 An approved corrosion resistant flame arrester is to be provided in the exhaust system. The flame arrester is to be constructed and tested to a recognised Standard. The flame arrester is to be fitted as close to the engine as possible with good access for inspection and replacement. The flame arrester can be omitted if the exhaust terminates in a safe area.

7.1.8 A spark arrester is to be fitted in the exhaust system downstream of the flame arrester. The spark arrester is to be constructed and tested to a recognised Standard.

7.1.9 It is recommended that a back pressure indicator is fitted to the exhaust manifold to provide prior warning of exhaust flame arrester fouling.

7.1.10 The engine crankcase breather pipe is to be fitted with a flame arrester. For engines in enclosed Zone 2 areas the breather pipe is to be led to the open atmosphere. The breather pipe is not to be led to the engine induction system.

7.1.11 The engine crankcase is to operate at a small positive pressure.

7.1.12 With the engine at maximum continuous rating and temperatures stabilised, no surface temperature on the engine or exhaust system is to exceed 200°C.

7.1.13 Ventilation fan blades and belts are to be of the anti-static type. The combination of materials for fan impellers and the housing are to be non-sparking under both normal and fault conditions.

7.1.14 Engine starting systems are not to introduce a source of ignition external to the engine. The system is to have appropriate safe type certification, or to be capable of being demonstrated as being of a safe type by appropriate testing.

7.1.15 The engine is not to be capable of running in reverse.

7.1.16 Fuel supply is to be capable of being shut off manually and automatically in the event of:

- overspeeding;
- high exhaust temperature, *see* 7.1.17;
- high cooling water temperature;
- low lubricating oil pressure.

7.1.17 The high exhaust temperature sensor is to be located upstream of the exhaust flame arrester. The high exhaust temperature sensor and engine shut-down on high exhaust temperature can be omitted if the exhaust pipe terminates in a safe area.

7.1.18 Basic operating instructions should be permanently attached to the unit giving details of stop, start and emergency procedures.

7.1.19 Where an engine is fitted inside any enclosure, the following requirements are to be complied with as applicable:

(a) Where an engine is located inside an enclosed Zone 2 hazardous area, the space is to be independently ventilated at a recommended minimum rate of 20 air changes per hour whilst the engine is running and 12 air changes per hour when stopped.

(b) For engines placed inside enclosures of any type it is recommended that fire and gas sensors be provided inside the enclosure, suitably alarmed to a continuously manned control room.

7.1.20 A hydraulic proof test at a gauge pressure of 5 bar or 1,5 times the maximum pressure obtained in explosion tests in accordance with 7.1.21 is to be witnessed on the induction and exhaust system components without showing signs of leakage.

7.1.21 For engines of 370 kW (500 shp) and above, the induction and exhaust systems are to be explosion tested to a recognised Standard without showing signs of damage or flame transmission to the atmosphere. The maximum explosion pressure is to be recorded and used in the hydraulic proof test in 7.1.20.

7.1.22 Complete engine units and driven components are to be examined and tested at the manufacturer's works or other suitable works before being put into service. Thereafter, the complete unit is to be examined annually and the original certificate endorsed or as otherwise agreed to ensure a permanent written record of survey. It is recommended that time clocks of the non-resetting type be fitted to the engine.

7.1.23 Where an engine manufacturer carries out satisfactory type tests on an engine or series of engines and subsequently provides conversion kits for similar engines, proof tests can be waived. However, each converted engine is to be shop-tested in accordance with 7.1.22.

■ *Section 8* Electrical equipment for use in explosive gas atmospheres

8.1 General

8.1.1 The installation of electrical equipment in areas containing flammable gas or vapour and/or combustible dust is to be minimised as far as is consistent with operational necessity and the provision of lighting, monitoring, alarm or control facilities enhancing the overall safety of the unit.

8.1.2 Compliance with IEC 60092-502: *Electrical Installations in Ships – Tankers – Special Features*, where directly relevant, may be accepted as meeting the requirements of this Section.

8.1.3 The requirements for electrical equipment for use in explosive gas atmospheres are given in Pt 6, Ch 2,14.2 and 14.3 of the Rules for Ships, which are to be complied with where applicable.

8.1.4 Additions or amendments to these requirements are given in 8.1.5 to 8.1.15.

8.1.5 In locations classified as Zone 0, only intrinsically safe equipment of category 'ia', or simple apparatus as defined in Pt 6, Ch 2,14.2.4(b) of the Rules for Ships and complying in full with the relevant requirements of IEC 60079 for intrinsic safety, category 'ia', is permitted.

8.1.6 In locations classified as Zone 1, only the following equipment may be installed:

- Equipment having a type of protection listed under Pt 6, Ch 2,14.2.5 of the Rules for Ships.
- Equipment as described under Pt 6, Ch 2,14.2.6(c) of the Rules for Ships, arranged to be de-energised automatically on loss of pressurisation.

8.1.7 In locations classified as Zone 2, and on open deck in well-ventilated positions not within 3 m of any flammable gas or vapour outlet, equipment having the types of protection listed under Pt 6, Ch 2,14.2.5 of the Rules for Ships or as described under Pt 6, Ch 2,14.2.6 of the Rules for Ships may be installed.

8.1.8 Any electrical equipment which has to remain operational during catastrophic conditions (e.g., rupture of a process vessel or pipe), whether or not installed in a hazardous zone or location, is to be suitable for use in an explosive gas atmosphere. Such equipment is to be of a type permitted within Zone 1 locations, unless it is demonstrated that the equipment is appropriately protected against potentially coming into contact with a flammable atmosphere, by being located in an enclosed safe area with appropriate mitigating measures (i.e., enclosed safe area is equipped with gastight barriers, gastight doors, rated gas dampers, suitable gas detection within the enclosure and its ventilation air intakes, etc.).

8.1.9 Flame-proof enclosures and intrinsically safe electrical apparatus, and apparatus incorporating flame-proof or intrinsically safe components or otherwise tested or certified for particular groups, shall, with reference to the group(s) of gas(es) that may be present, be selected with reference to IEC/TR 60079-20, *Electrical apparatus for explosive gas atmospheres* – Part 20: Data for flammable gases and vapours, relating to the use of electrical apparatus.

8.1.10 The electrical apparatus shall be so selected that its maximum surface temperature as indicated by its temperature class, or otherwise documented, will not reach the auto-ignition temperature of any gas or vapour, or mixture of gases or vapour, which can be present. The ambient temperature range for which the apparatus is suitable is to be taken to be minus 20°C to 40°C, unless otherwise stated, and account is to be taken of this when assessing the suitability of the equipment for the auto-ignition temperature of the gases encountered.

8.1.11 Cables are not permitted to pass through locations classified as Zone 0, and are permitted to enter such locations only where required for the operation of any electrical equipment located therein.

8.1.12 Cables are to be either:

(a) mineral insulated with copper sheath, or
(b) armoured or braided, except where:
  (i) the cable is associated with an intrinsically safe circuit; or
  (ii) the cable does not pass into or through any location classified as Zone 1, and is routed or protected so as to present only a low risk of mechanical damage; or
  (iii) a cable of flexible construction is demanded by operational requirements, and its construction, routeing and means of support are such as to present only a low risk of mechanical damage; or
  (iv) the cable is installed within a conduit system meeting the relevant requirements of IEC 60079-14.

8.1.13 Cables associated with intrinsically safe circuits are to be used only for such circuits. They are to be physically separated from cables associated with non-intrinsically safe circuits, e.g., neither installed in the same protective casing nor secured by the same fixing clip, except where alternative arrangements are permitted by IEC 60079-14.

8.1.14 No more than one intrinsically safe circuit should be run in any multicore cable unless:

(a) no circuit is required to be of category 'ia', and, either:
  (i) the cable is run or protected so as to present little risk of its suffering mechanical damage; or
  (ii) each intrinsically safe circuit is contained within an earthed metallic screen; or
(b) it can be shown that no combination of faults between the intrinsically safe circuits within the cable can lead to an unsafe condition.

8.1.15 Cabling, wiring, and connections within enclosures containing more than one intrinsically safe circuit or containing both intrinsically safe and other circuits, are to be arranged in accordance with the relevant requirements of IEC 60079-11 and IEC 60079-14 so as to minimise the risk of inadvertent interconnections between different circuits.

8.1.16 Metal coverings of cables installed in hazardous zones or spaces are to be effectively earthed, at both ends at least, except where otherwise permitted by IEC 60079-14.

■ *Section 9* Additional requirements for electrical equipment on oil storage units for the storage of oil in bulk having a flash point not exceeding 60°C (closed-cup test)

9.1 General

9.1.1 The additional requirements for electrical equipment on oil storage units for the storage of oil in bulk having a flash point not exceeding 60°C (closed-cup test) are given in this Section.

9.1.2 Spaces or locations associated with or close to the oil storage arrangements are to be classified in accordance with the zonal concept by direct application of IEC 60092-502: *Electrical Installations in Ships – Tankers – Special Features*. Alternatively, classification may be carried out by application of the methods given in IEC Publication 60079-10-1 or EI (formerly IP) Part 15, taking into account the probable frequency, duration and rates of leakages of flammable material from all sources (including structural defects) and the degree and availability of ventilation at the location. Consideration will then be given to the installation of equipment other than that defined within this Section. Such equipment is to meet the requirements of Section 8 for the relevant zone.

9.1.3 Where the Rules for Ships refer to 'cargo oil/cargo tanks', this also applies to 'integral oil/oil storage tanks'.

9.1.4 Electric cables are not to be installed in dangerous zones or spaces, except as permitted by Section 8.

9.1.5 In addition to the requirements of Section 8, cables, other than those of intrinsically safe circuits, in hazardous zones or spaces, or which may be exposed to stored oil, oil vapour or gas, are to be either:

(a) mineral insulated with copper sheath; or
(b) armoured or braided (for mechanical protection and earth detection) with non-metallic impervious sheath.

9.1.6 Where electrical equipment is not suitable for a hazardous area into which the space has an opening, the electrical supply to the equipment is to be disconnected, provided shutting down the equipment will not introduce a hazard. In this case, an alarm may be given, in lieu of shut-down, upon loss of overpressure or ventilation, and a means of disconnection of the electrical equipment, capable of being controlled from a manned station, provided in conjunction with an agreed operational procedure. Where the means of disconnection (whether controlled automatically or manually) is located within the space, it is to be equipment of a type suitable for use in a Zone 1 location.

9.1.7 Within any space classified as safe by virtue of pressurisation, any electrical equipment required to operate upon loss of overpressure and lighting fittings and equipment within the air-lock is to be of a type suitable for a Zone 1 location. Means are to be provided to prevent electrical equipment, other than that suitable for a Zone 1 location, being energised until the atmosphere within the space is made safe, by air renewal of at least 10 times the internal volume of the space.

■ *Section 10*
Additional requirements for electrical equipment on units for the storage of liquefied gases in bulk

10.1 General

10.1.1 *See* Chapter 10 of the *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquefied Gases in Bulk*.

■ *Section 11*
Additional requirements for electrical equipment on units intended for the storage in bulk of other flammable liquid cargoes

11.1 General

11.1.1 *See* Chapter 10 of the *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquid Chemicals in Bulk*.

■ *Section 1* General

1.1 Application

1.1.1 The requirements for fire and gas detection systems and other safety systems are to be in accordance with Chapter 1. The requirements for hazardous areas and ventilation are to comply with Chapter 2.

1.1.2 Compliance with the requirements for fire safety of the National Administrations in the country in which the unit is registered and in the area of operation, where applicable, is to be demonstrated by the issue of appropriate certification in accordance with Pt 1, Ch 2,1.

1.1.3 In addition to the requirements of 1.1.1 and 1.1.2, units with production and process plant are to comply with the additional requirements given in Section 3.

1.1.4 Units with crude oil storage tanks are, in general, to comply with the relevant requirements for tankers detailed in SOLAS Ch II-2 and IMO Fire Fighting System (FSS) Code Resolution MSC.98(73). Where this is not practicable owing to the general construction of the unit, special consideration will be given to other arrangements which provide equivalent protection, *see also* Pt 3, Ch 3,1.4.

1.1.5 The definitions given in Section 2 are, in general, in accordance with the *IMO Code for the Construction and Equipment of Mobile Drilling Units*, 2009 (hereinafter referred to as 2009 MODU Code) and are included for reference purposes only. Where applicable, reference to these definitions may be used in other Parts of these Rules.

1.1.6 For drilling units, specific reference should be made to the requirements of the 2009 IMO MODU Code Resolution A.1023(26) Ch 9 for fire safety.

1.2 Submission of plans and data

1.2.1 The requirements for submissions of plans and data are given in 1.2.7 to 1.2.10, which are to be complied with where applicable.

1.2.2 Additional requirements with respect to unit types as indicated in this Section should also be complied with, where applicable, as in 1.2.3 to 1.2.10.

1.2.3 In addition to the requirements of Chapter 1 of these Rules, when LR is authorised to carry out approvals of fire protection, detection and extinction arrangements on behalf of a National Administration or the requirements of Pt 1, Ch 2,1.1.13 of these Rules are applicable, the plans and documents detailed below and required by 1.2.7 to 1.2.10 are to be submitted for approval, together with all additional relevant information, such as the intended function of the unit, the gross tonnage and the power of machinery.

1.2.4 The requirements for active and passive type fire protection systems are to be clearly defined within the unit's 'Fire and Explosion Evaluation' (FEE) report, *see* 2.4, which is to be submitted for information with the plans required below.

1.2.5 In the case of units with production and process plant, the FEE Report required by 1.2.4, 1.2.8, 1.2.9 and 1.2.10 is to be submitted for approval with full details of the water deluge system and/or water monitor system as required by 3.4.

1.2.6 For units with production and process plant, plans of escape routes with details of their protection are to be submitted for approval as required by 3.6.

1.2.7 For fire protection, the following plans and documents are to be submitted:

- A general arrangement plan showing escape stairways and fire compartmentation bulkheads and decks, including machinery spaces, control stations, accommodation and service spaces, corridor bulkheads and stairway enclosures.
- A ventilation plan showing the ducts and any dampers in them, and the position of the controls for stopping the system.
- A plan showing the automatic fire detection and fire alarm system.
- A plan showing the location and arrangement of the emergency stop for the oil fuel unit pumps and for closing the valves on the pipes from oil fuel tanks.
- A plan showing the details of the construction of the fire protection bulkheads, decks and deck heads and the particulars of any surface laminates incorporated in them.
- Copies of the Certificates of Approval by National Authorities in respect of all 'A' and 'B' Class fire divisions, non-combustible materials and materials having low flame spread characteristics, etc., which are intended to be used but have not been approved by LR.
- A general arrangement plan showing the purpose of each room or compartment and the fire classification of the bulkheads, decks, deck heads and doors of the accommodation and service spaces, control rooms and machinery compartments.
- A plan showing the construction of the fire doors.
- A plan showing any proposed remote control system for closing doors.
- A plan showing any proposed water sprinkler system.
- A plan showing the location and arrangement of the emergency stop for the oil fuel unit pumps and for closing valves on the pipes from oil fuel tanks.
- A plan of any proposed gas detection and alarm system.

1.2.8 For fire-extinguishing, the following plans and particulars are to be submitted:

- A plan showing the layout and construction of the fire main, including the main and emergency fire pumps, isolating valves, pipe sizes and materials and the cross connections to any other system.
- A plan showing details of each fixed fire-fighting system, including calculations for the quantities of the media used and the proposed rates of application.
- A general arrangement plan showing the disposition of all the fire-fighting equipment including the water fire main, all fixed fire-extinguishing systems, the disposition of all portable and non-portable extinguishers and the types used and the position and details of the fireman's outfits.
- A plan showing the layout and construction of hydrants, hoses and nozzles including their material and type and the international shore connections.

1.2.9 For fire control, general arrangement plans are to be submitted:

(a) showing clearly for each deck:
  - the control stations;
  - the various fire sections enclosed by 'H' Class divisions, *see* 2.6.2;
  - the various fire sections enclosed by 'A' Class divisions, *see* 2.6.1; and
  - the fire sections enclosed by 'B' Class divisions, *see* 2.6.3;

(b) together with particulars of the:
  - fire alarms;
  - detecting systems;
  - sprinkler/deluge systems (if any);
  - fire-extinguishing appliances;
  - means of access to different compartments, decks, etc.; and
  - ventilating system, including particulars of the fan control positions, the position of dampers and identification numbers of the ventilating fans serving each fire section.

1.2.10 There is to be permanently exhibited in all units, for the guidance of those on board, the general arrangement plans as required by 1.2.9.

(a) Alternatively, the aforementioned details may be set out in a booklet, a copy of which is to be supplied to each responsible person, and one copy at all times is to be kept up to date, any alterations being recorded thereon as soon as practicable.

(b) All descriptions in such plans and booklets are to be in the official language of the Flag State. If the language is neither English nor French, a translation into one of those languages is to be included.

(c) In addition, instructions concerning the maintenance and operation of all the equipment and installations on board for the fighting and containment of fire are to be kept under one cover, readily available in an accessible position.

■ *Section 2* Definitions

2.1 Materials

2.1.1 **Non-combustible material** means a material which neither burns nor gives off flammable vapours in sufficient quantity for self-ignition when heated to approximately 750°C, this being determined in accordance with the Fire Test Procedures Code. Any other material is a 'combustible material'.

2.1.2 **Steel or other equivalent material** means any non-combustible material which, by itself, or due to insulation provided, has structural and integrity properties equivalent to steel at the end of the applicable exposure to the standard fire test (e.g., aluminium alloy with appropriate insulation).

2.2 Fire test

2.2.1 A **standard fire test** is a test in which specimens of the relevant bulkheads or decks are exposed in a test furnace to temperatures corresponding approximately to the standard time-temperature curve in accordance with the test method specified in the Fire Test Procedures Code. The specimen is to have an exposed surface of not less than 4,65 m^2 and height (or length of deck) of 2,44 m resembling as closely as possible the intended construction and including where appropriate at least one joint. The standard time-temperature curve is defined by a smooth curve drawn through the following temperature points measured above the initial furnace temperature:

At the end of the first 5 minutes	576°C
At the end of the first 10 minutes	679°C
At the end of the first 15 minutes	738°C
At the end of the first 30 minutes	841°C
At the end of the first 60 minutes	945°C.

2.2.2 A **hydrocarbon fire test** is one in which the specimens defined for a standard fire test are exposed in a test furnace to temperatures corresponding approximately to a time-temperature curve relating to, and defined by, a smooth curve drawn through the following temperature points measured above the initial furnace temperature:

at the end of the first 3 minutes	880°C
at the end of the first 5 minutes	945°C
at the end of the first 10 minutes	1032°C
at the end of the first 15 minutes	1071°C
at the end of the first 30 minutes	1098°C
at the end of the first 60 minutes	1100°C.

2.2.3 A **jet-fire test** is used to determine how effective the passive fire protection materials are in withstanding an actual jet fire. The test is not intended to replace the hydrocarbon fire test. Some Administrations require fire protection materials to be assessed by this method and, where requested, LR can advise on the detailed requirements. *See* Pt 3, Appendix A for applicable Fire Standards.

2.3 Flame spread

2.3.1 **Low flame spread** means that the surface thus described will adequately restrict the spread of flame in accordance with the Fire Test Procedures Code, this being determined by an acceptable test procedure.

2.4 Fire and Explosion Evaluation (FEE)

2.4.1 The FEE is an assessment of the potential fire loadings and blast pressures, based on the specific hazards associated with the general layout of the unit, production and process activities and operational constraints.

2.4.2 These Rules allow for the dimensioning of explosion loads to be based on probabilistic risk assessment techniques. A methodology to establish risk based explosion loads based on such a probabilistic approach is given in LR's *Guidelines for the Calculation of Probabilistic Explosion Loads*.

2.5 Temporary refuge

2.5.1 This is a designated area that is to provide adequate facilities to protect the personnel from fire, explosion and associated hazards during the period for which they may need to remain on a unit following an uncontrolled incident, and for enabling their evacuation, escape and rescue. It is also to provide adequate facilities for monitoring and control of any major incident.

2.6 Fire divisions, spaces and equipment

2.6.1 **'A' Class divisions** are those divisions formed by bulkheads and decks which comply with the following criteria:

(a) They are to be constructed of steel or other equivalent material.
(b) They are to be suitably stiffened.
(c) They are to be so constructed as to be capable of preventing the passage of smoke and flame up to the end of the one-hour standard fire test.
(d) They are to be insulated with approved non-combustible materials such that the average temperature of the unexposed side will not rise more than 140°C above the original temperature, nor will the temperature, at any one point, including any joint, rise more than 180°C above the original temperature, within the time listed below:

Class 'A-60'	60 minutes
Class 'A-30'	30 minutes
Class 'A-15'	15 minutes
Class 'A-0'	0 minutes

(e) In accordance with the Fire Test Procedures Code, a test of a prototype bulkhead or deck may be required to ensure that it meets the above requirements for integrity and temperature rise.

2.6.2 **'H' Class divisions** are those divisions formed by fire walls and decks which comply with the construction and integrity requirements for 'A' Class divisions, 2.6.1(a) and (b) and with the following:

(a) They are to be so constructed as to be capable of preventing the passage of smoke and flame up to the end of the one hour hydrocarbon fire test. (Note that some administrations may require the 'H' Class division integrity to be maintained for 120 minutes).
(b) They are to be insulated with approved non-combustible materials such that the average temperature, on the unexposed side, when exposed to a hydrocarbon fire test, will not rise more than 140°C above the original temperature, nor will the temperature at any one point, including any joint, rise more than 180°C above the original temperature within the time listed below:

Class 'H-120'	120 minutes
Class 'H-60'	60 minutes
Class 'H-0'	0 minutes.

(c) A test of a prototype fire wall or deck may be required to ensure that it meets the above requirements for integrity and temperature rise.

2.6.3 **'B' Class divisions** are those divisions formed by bulkheads, decks, ceilings or linings which comply with the following criteria:

(a) They are to be so constructed as to be capable of preventing the passage of flame to the end of the first half hour of the standard fire test.
(b) They are to have an insulation value such that the average temperature of the unexposed side will not rise more than 140°C above the original temperature, nor will the temperature at any one point, including any joint, rise more than 225°C above the original temperature, within the time listed below:

Class 'B-15'	15 minutes
Class 'B-0'	0 minutes

(c) They are to be constructed of approved non-combustible materials and all materials used in the construction and erection of 'B' Class divisions are to be non-combustible, with the exception that combustible veneers may be permitted, provided they meet other appropriate requirements of this Chapter.
(d) In accordance with the Fire Test Procedures Code, a test of a prototype division may be required to ensure that it meets the above requirements for integrity and temperature rise.

2.6.4 **'C' Class divisions** are divisions to be constructed of approved non-combustible materials. They need meet neither requirements relative to the passage of smoke and flame nor limitations relative to the temperature rise. Combustible veneers are permitted provided they meet the requirements of this Chapter.

2.6.5 **Continuous 'B' Class ceilings or linings** are those 'B' Class ceilings or linings which terminate only at an 'A' or 'B' Class division.

2.6.6 **Machinery spaces** of category A are all spaces which contain internal combustion-type machinery used either:
(a) for main propulsion; or
(b) for other purposes where such machinery has in the aggregate a total power of not less than 375 kW;
or which contain any oil-fired boiler or oil fuel unit; and trunks to such spaces.

2.6.7 **Machinery spaces** are all machinery spaces of Category 'A' and all other spaces containing propelling machinery, boilers and other fired processes, oil fuel units, steam and internal combustion engines, generators and major electrical machinery, oil filling stations, refrigerating, stabilising, ventilation and air conditioning machinery, and similar spaces, and trunks to such spaces.

2.6.8 **Control stations** are those spaces in which the unit's radio or main navigating equipment or the emergency source of power is located or where the fire recording or fire control equipment or the dynamic positioning control system is centralised or where a fire-extinguishing system serving various locations is situated. In the case of column-stabilised units, a centralised ballast control station is a 'control station'. However, for purposes of the application of Chapter 3, the space where the emergency source of power is located is not considered as being a control station.

2.6.9 For definitions and categories of hazardous areas including 'enclosed' and 'semi-enclosed' spaces, *see* Ch 2,1.2.

2.6.10 **Drilling, process plant** and **industrial machinery and components** are the machinery and components which are used in connection with the operation of drilling, production and process systems.

2.6.11 **Working spaces** are those open or enclosed spaces containing equipment and processes, associated with drilling operations, which are not included in hazardous areas and machinery spaces.

2.6.12 **Accommodation spaces** are those used for public spaces, corridors, lavatories, cabins, offices, hospitals, cinemas, games and hobbies rooms, pantries containing no cooking appliances and similar spaces. 'Public spaces' are those portions of the accommodation which are used for halls, dining rooms, lounges and similar permanently enclosed spaces.

2.6.13 **Service spaces** are those used for galleys, pantries containing cooking appliances, lockers and storerooms, workshops other than those forming part of the machinery spaces, and similar spaces and trunks to such spaces.

2.6.14 **Oil fuel unit** is the equipment used for the preparation of oil fuel for delivery to an oil-fired boiler, or equipment used for the preparation for delivery of heated oil to an internal combustion engine, and includes any oil pressure pumps, filters and heaters dealing with oil at a pressure of more than 0.18 N/mm^2. Oil transfer pumps are not considered oil fuel units.

2.6.15 **Crude oil** is any oil occurring naturally in the earth, whether or not treated to render it suitable for transportation, and includes:
(a) crude oil from which certain distillate fractions may have been removed; and
(b) crude oil to which certain distillate fractions may have been added.

2.6.16 **Storage spaces** are spaces used for bulk storage and trunks to such spaces, e.g., crude oil storage tanks on oil storage units.

■ *Section 3*
Additional requirements for units with production and process plant

3.1 General requirements for fire-water mains and pumps

3.1.1 Each unit is to be provided with a pressurised wet pipe fire main so equipped and arranged such that water for fire-fighting purposes can be supplied to any part of the unit. The fire main is to be:
(a) Connected to at least two independent fire pumping units, adequately segregated such that a single incident will not compromise the required fire-water supply, as defined in the unit's FEE Report. Each pumping unit is to be capable of providing sufficient fire-water to satisfy the maximum credible fire water demand.
(b) Designed to deliver the pressure and flow requirements for the simultaneous operation of water-based active fire protection systems (deluge waterspray, monitors, hoses, etc.) sufficient to meet the requirements of these systems as defined in the FEE Report. This is typically to be the single largest credible fire area (where deluge/ waterspray systems are installed), plus any anticipated manual fire fighting demand (monitors/hose streams).
(c) Where required in the FEE Report, the total fire pumping capability is also to cater for fire escalating to adjacent areas, i.e., typically where suitable fire divisional barriers do not exist.
(d) Capable of delivering at least one jet simultaneously from each of any two fire hydrants, hoses and 19 mm nozzles, while maintaining a minimum pressure of 3,5 bar (3,5 kgf/cm^2) at any hydrant. In addition, where a foam system is provided for protection of the helicopter deck and is served by the fire main, a pressure of 7 bar (7 kgf/cm^2) at the foam installation is to be capable of being simultaneously maintained.

3.1.2 The arrangements of the pumps, sea suctions and sources of power are to be such as to ensure that a fire in any one space would not put more than one required pumping unit out of action.

3.1.3 Suitable provision is to be made for the automatic start-up of the fire pumps when any fire-fighting appliance supplied with water from the fire main is operated. Provision is also to be made for the start-up of the pumps locally and remotely from a continuously manned space or fire-control station. Once activated, the pumps are to be capable of continuous unattended operation for at least 18 hours.

3.2 Fire mains

3.2.1 The diameter of any fire-water main and individual service pipes is to be sufficient for the effective distribution of the maximum required discharge from the required pumps operating simultaneously.

3.2.2 With the required pumps operating simultaneously, the pressure maintained in the fire main is to be adequate for the safe and efficient operation of all equipment supplied therefrom. The arrangements are to be such that the hand-held fire-fighting equipment supplied from the main may be safely used by one person.

3.2.3 Where practicable, the fire main is to be routed clear of hazardous areas and be arranged in such a manner as to make maximum use of any thermal shielding or physical protection afforded by the structure of the unit.

3.2.4 The fire main is to be provided with isolating valves located so as to permit optimum utilisation of the main in the event of physical damage to any part of the main.

3.2.5 The fire main is not to have connections other than those necessary for fire-fighting purposes.

3.2.6 All practicable precautions consistent with having water readily available are to be taken to protect the fire main against freezing.

3.2.7 Materials readily rendered ineffective by heat are not to be used for fire mains and hydrants unless adequately protected. The pipes and hydrants are to be so placed that the fire hoses may be easily coupled to them.

3.3 Fire pumps

3.3.1 Any diesel-driven power source is to be capable of being readily started in its cold condition down to a temperature of 0°C, except where agreed otherwise with LR. If this is impracticable, or if lower temperatures are likely to be encountered, consideration will be given to the provision and maintenance of heating arrangements, so that ready starting will be assured. The engine is to be equipped with an approved starting device (e.g., starting battery), independent hydraulic system, or independent starting air system, having a capacity sufficient for at least six starts of the emergency fire pump within a 30 minute period with at least two starts within the first 10 minutes.

3.3.2 Any service fuel tank is to contain sufficient fuel to enable the pump to run on full load for at least 18 hours.

3.3.3 Under both normal and emergency conditions, any compartment in which a pump unit is located is to be accessible, properly illuminated and efficiently ventilated.

3.3.4 Every centrifugal pump which is connected to the fire main is to be fitted with a non-return valve.

3.3.5 Relief valves are to be provided in conjunction with all pumps connected to the fire main if the pumps are capable of developing a pressure exceeding the design pressure of the fire main, hydrants and hoses. Such valves are to be so placed and adjusted as to prevent excessive pressure in the fire main system.

3.3.6 Means are to be provided for testing the output capacity of each fire pumping unit, in accordance with NFPA (20) or an equivalent Standard.

3.3.7 The provision of surge relief devices is also to be considered at the fire pumps, to prevent over-pressurisation of the mains on fire pump start-up. Such devices are to reset automatically once the excess pressure has been relieved.

3.3.8 The fire-water pump stop should be local only. Except during testing, any alarms from pump monitoring systems should not automatically stop a running fire pump with the exception of engine overspeed for fire-water pump engine drive units. Fire detection at the fire-water pump should not stop the pump or inhibit the start of the fire-water pump driver. Confirmed hydrocarbon detection in the air inlet of the driver should inhibit the pump start but should not trip a running fire-water pump.

3.3.9 With reference to Section 3.3.8, the design of the fire-water pump drive system shall ensure, so far as practical, that the fire-water pump drive set does not constitute an ignition source for potential hydrocarbon gas, which may migrate to the pump drive enclosure on a hydrocarbon release incident. As such, the fire-water pump drives should be located in a non-hazardous area of the MOU and housed in a non-hazardous enclosure with ventilation designed to be maintained an over-pressure of at least 50 Pa in relation to adjacent external spaces. The fire-water pump drive enclosure is to be constructed with suitable fire rated and gastight barriers, suitable fire rated and gastight doors, suitable fire rated and gas rated dampers. The design of the fire-water pump drive shall be such that on gas detection on the enclosure ventilation air intakes, the drive is capable of continued operation with the enclosure ventilation shut-down, ventilation fire and gas dampers closed and all entrances to the enclosure closed.

3.4 Water deluge systems and water monitors

3.4.1 The topside area of each unit is to be provided with a water deluge system and/or water monitor system by means of which any part of the unit containing equipment used for storing, conveying or processing hydrocarbon resources (other than fuels for use on the unit) can be protected in the event of fire. Areas containing equipment requiring water protection include the following:

- Areas containing equipment (including piping) through which hydrocarbons will flow during well test operations.
- Crude oil and gas manifolds/piping (not fuel gas), including piping routed over bridges between platforms.
- Crude oil pumps.
- Crude oil storage vessels.
- De-aeration/filtration equipment (if using gas).
- Emergency shut-down valves.
- Flare knock-out drums.
- Gas compressors.
- Gas liquids/concentrate storage vessels.
- Glycol regeneration plant.
- Liquefaction plant.
- Pig launchers/receivers.
- Process pressure vessels.
- Process separation equipment.
- Riser connections.
- Swivel stack areas.
- Turret areas.

3.4.2 Water deluge systems and water monitors are to be connected to a continuously pressurised water main supplied by at least two pumps capable, with any one pump out of action, of maintaining a supply of water at a pressure sufficient to enable the system or monitors to operate at the required discharge rates to meet the water demand of the largest single area requiring protection in accordance with the FEE.

3.4.3 The quantity of water supplied to any part of the production and process plant facility is to be at least sufficient to provide exposure protection to the relevant equipment within that part, and where appropriate, local principal load-bearing structural members. 'Exposure protection' means the application of water spray to equipment or structural members to limit absorption of heat to a level which will reduce the possibility of failure.

3.4.4 Generally, the minimum water application rate is to be not less than 10 litres/minute over each square metre of exposed surface area requiring protection within the appropriate reference area. Other water application rates in accordance with a recognised Standard or Code which meets the requirements of 3.2.1 will be considered. A reference area is a horizontal area bounded completely by:

(a) vertical 'A' or 'H' Class divisions; or
(b) the outboard extremities of the unit; or
(c) a combination of (a) and (b).

3.4.5 Each part requiring water protection is to be provided with a primary means of application, which may be:

(a) a fixed system of piping fitted with suitable spray nozzles; or
(b) water monitors; or
(c) a combination of (a) and (b).

NOTE
Water monitors may only be used for the protection of equipment sited in essentially open areas.

3.4.6 The layout of piping and nozzles within each reference area is to be such that all parts requiring protection are exposed to the direct impingement of water spray. The piping system may be subdivided within each reference area in accordance with the disposition of equipment and structure.

(a) Spray nozzles are to be of the open type and fitted with deflector plates or equivalent devices capable of reducing the water discharge to a suitable droplet size. The relative location and orientation of individual nozzles is to be in keeping with their established discharge characteristics.
(b) The water pressure available at the inlet to a system or an individual section is to be sufficient to ensure efficient operation of all nozzles in the system or section.

3.4.7 Water monitors may be operated either remotely or locally. Each monitor arranged solely for local operation is to be:

- Provided with an access route which is remote from the part requiring protection; and
- Sited so as to afford maximum protection to the Operator from the effects of radiant heat.

Each monitor is to have sufficient movement in the horizontal and vertical planes to permit the monitor to be brought to bear on any part protected by it. Means are to be provided to lock the monitor in any position. Each monitor is to be capable of discharging under jet and spray conditions.

3.4.8 With reference to the above requirements for water deluge and water monitor coverage, it may be possible to utilise passive fire protection in place of fire-water cover over certain facilities dependent upon the finding of the FEE. Refer to Section 3.6

3.5 Hydrants, hoses and nozzles

3.5.1 The number and position of the hydrants are to be such that at least two jets of water, not emanating from the same hydrant, one of which is to be from a single length of fire hose, may reach any part of the unit normally accessible to those on board while the unit is being navigated or is engaged in drilling operations. A hose is to be provided for every hydrant.

3.5.2 A cock or valve is to be fitted to serve each fire hose so that any fire hose may be removed while the fire pumps are operating.

3.5.3 Fire hoses are to be of type approved material and be sufficient in length to project a jet of water to any of the spaces in which they may be required to be used. Their maximum length, in general, is not to exceed 18 m. Every fire hose is to be provided with a dual-purpose nozzle and the necessary couplings. Fire hoses, together with any necessary fittings and tools, are to be ready for use at any time and should be kept in conspicuous positions near the water service hydrants or connections.

3.5.4 Standard nozzle sizes are to be 12 mm, 16 mm and 19 mm or as near thereto as possible. Larger diameter nozzles may be permitted if required as a result of special considerations.

3.5.5 For machinery spaces and exterior locations, the nozzle size is to be such as to obtain the maximum discharge possible from two jets at the pressure specified in 3.1.1(d) from the smallest pump, provided that a nozzle size greater than 19 mm need not be used. For accommodation and service spaces, a nozzle size greater than 12 mm need not be used.

3.5.6 The jet throw at any nozzle is to be about 12 m.

3.5.7 All nozzles are to be of an approved dual purpose type (i.e., spray/jet type) incorporating a shut-off.

3.5.8 The surface unit should be provided with at least one international shore connection complying with SOLAS Regulation II-2/10-2.1.7 and the FSS Code. Facilities should be available enabling such a connection to be used on any side of the unit.

3.6 Passive fire protection

3.6.1 As outlined in 1.2.1, 1.2.2 and 3.4.8, the additional requirements for passive type fire protection systems to the topsides process modules, and associated plant, are to be evaluated within the unit's FEE Report. The specific requirements for passive fire protection (PFP) systems are to be designed to provide adequate hydrocarbon containment to prevent escalation and enable safe evacuation of personnel to the 'Temporary Refuge'.

3.6.2 With regard to the performance requirements for PFP systems, particular attention is to be given to the potential thermal and erosive effects of hydrocarbon jet-fires in the initial phase of a topsides incident. Consideration is also to be given to the ongoing thermal effects from pool fires. The duration of these events is to be examined in the project FEE in conjunction with the process systems.

3.7 Fixed pressure water spraying and water-mist systems

3.7.1 Additional consideration may be given to the installation of Fixed Pressure Water Spraying and Water-Mist fire extinguishing systems within internal machinery spaces, cabins and low risk areas. Specific functionality requirements for these systems should be evaluated and clearly defined within the unit's FEE Report.

3.7.2 With regard to the performance requirements for Fixed Pressure Water Spraying and Water-Mist fire extinguishing systems, particular attention should be given to the design acceptance criteria outlined in the FSS Code (Resolution MSC.98(73)) Chapter.7 as amended by Resolution MSC.217(82) in Document: MSC 82/24/Add.1.

3.7.3 MSC/Circ.1165 (Machinery Spaces) and A.800(19) (Accommodation Areas) should also be referenced for issues associated with the testing of these systems.

3.7.4 Alternative international Codes (such as NFPA 750) may also be considered for project specific applications.

■ *Section 4* **Means of escape**

4.1 General requirements

4.1.1 For general requirements for means of escape, *see* SOLAS Ch II-2, Part D, Ch III and IMO Life-Saving Appliance (LSA) Code Resolution MSC.48(66). For drilling units, specific reference should be made to the requirements of the 2009 IMO MODU Code Resolution A.1023(26) Ch 9.4 and Ch 10.

4.1.2 In addition to the requirements of the applicable SOLAS Regulations, escape ways on units with production and process plant are to be adequately protected against potential fire loadings emanating from the topsides plant and production facilities. The following objectives are to be considered when evaluating the unit's requirements for escape, evacuation and rescue:

- To maintain the safety of all personnel when they move to another location to avoid the effects of a hazardous event.
- To provide a refuge on the unit for as long as required to enable a controlled evacuation of the unit.
- To facilitate recovery of injured personnel.
- To ensure safe abandonment of the unit.

4.1.3 Where sufficient physical barriers do not exist, escape ways are to be protected by way of active (deluge cooling) or passive (fire screen) type systems.

4.1.4 Escape route widths are to be considered in relation to the number of personnel and individual occupancy of all topsides process and turret areas. Escape routes are to be provided to enable all personnel safely to evacuate an area, when they are directly affected by an incident.

4.1.5 In general, main escape ways from major process and production areas are to have a minimum clear width of 1000 mm, to enable the safe passage of potentially injured personnel (i.e., stretcher evacuees).

Section 5
Deckhouses and superstructures

5.1 Boundary bulkheads

5.1.1 Particular consideration is to be given to the potential effects of fire and blast impinging on exposed boundary bulkheads of accommodation spaces and/or temporary refuge. Where boundary bulkheads can be subjected to blast loading, the scantlings are to comply with Pt 4, Ch 3,4.16 and Ch 6,9.1.6.

5.2 Enclosed spaces

5.2.1 In addition to the requirements of Ch 2,4, enclosed spaces of deckhouses and superstructures used for accommodation and/or 'temporary refuge' are to be maintained at an over-pressure relative to the external area to prevent the potential ingress of smoke and hazardous gases, in the event of a major topsides incident.

5.2.2 With reference to 5.2.1, the design of the accommodation and/or 'temporary refuge' is to be such that the accommodation and/or 'temporary refuge' enclosure is to be supplied with a ventilation system designed to maintain an overpressure of at least 50 Pa in relation to adjacent external spaces. The ventilation air intakes to the accommodation and/or 'temporary refuge' are to be equipped with suitable hydrocarbon gas, smoke and/or toxic gas detection dependent upon the credible risks associated with the MOU. The accommodation and/or 'temporary refuge' enclosure is to be constructed with suitable fire rated and gastight barriers, suitable fire rated and gastight doors, suitable fire rated and gas rated dampers. The design of the accommodation and/or 'temporary refuge' enclosure shall be such that on hydrocarbon gas, smoke and/or toxic gas detection at the enclosure ventilation air intakes, dependent upon the credible risks associated with the MOU, the enclosure ventilation system will shut down and all ventilation fire and gas dampers will close in order to mitigate against potential hydrocarbon gas, smoke and/or toxic gas entering the accommodation and/or 'temporary refuge'.

5.2.3 With reference to 5.2.2, the design of the accommodation and/or 'temporary refuge' enclosure is to be designed with a suitable air leakage rate to mitigate against any potential hydrocarbon gas, smoke and/or toxic gas impairment on isolation of the accommodation and/or 'temporary refuge' enclosure ventilation. The air leakage rate for the accommodation and/or 'temporary refuge' enclosure should be based on the required endurance period of the accommodation and/or 'temporary refuge' enclosure in any potential credible hydrocarbon gas, smoke and/or toxic gas incident associated with the MOU.

5.3 Access doors

5.3.1 Access doors to spaces referred to in 5.2.1 are to be fitted with self-closing gastight doors that open outwards from the enclosed space. Special consideration will be given to spaces which are protected by mechanically ventilated air locks, *see also* Ch 2,4.

Rules and Regulations for the Classification of Mobile Offshore Units

Part 8
Corrosion Control

June 2013

LIFE MATTERS

Chapter Contents Part 8

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■ *Section 1* Corrosion protection

1.1 Application

1.1.1 The requirements cover the corrosion protection of mobile offshore units of the general types defined in Pt 1, Ch 2,2, *see also* Pt 3, Ch 1. Requirements are also given for riser systems, *see* Section 2.

1.1.2 All structural steel work is to be suitably protected against loss of integrity due to the effects of corrosion. In general, suitable protective systems may include coatings, metallic claddings, cathodic protection, corrosion allowances or other approved methods. Combinations of methods may be used when agreed by LR. Consideration should be paid to the design life and the maintainability of the surfaces in the design of the protected systems.

1.1.3 The basic Rule scantlings of the external submerged steel structure of units which are derived from Part 4 assume that a cathodic protection system will be effective and in use continually. Unless agreed otherwise with LR no corrosion allowance will be included in the approved scantlings, *see* Pt 3, Ch 1,5.

1.2 Zone definitions

1.2.1 The type of protection of the steelwork is to be suitable for the structural location of the unit and for this purpose the steel structure is to be considered in terms of zones.

1.2.2 **Submerged zone**. That part of the external structure below the maximum design operating draught.

1.2.3 **Boot topping zone**. That part of the external structure between the maximum design operating draught and the light design operating draught. For column-stabilised units, *see* Table 1.1.1.

1.2.4 **Splash zone**. That part of the external structure above the boot topping zone subject to wet and dry conditions.

1.2.5 **Atmospheric zone**. That part of the external structure above the splash zone.

Table 1.1.1 Minimum corrosion protection requirements for external structural steelwork

Unit type	Corrosion protection required and area		
	Zone	Structural steelwork	Method of protection required
Column-stabilised units	Submerged zone	Columns, lower hulls and bracings	Cathodic protection and coatings *See* Notes 1 and 4
	Boot topping and splash zones *See* Note 2	Columns, lower hulls and bracings	Coatings
	Atmospheric zone	All structure above the splash zone	Coatings only
Self-elevating units	Transit condition: Submerged, boot topping and splash zones	Main hull	Coatings only
	Elevated condition: Submerged zone	Legs, footings and mats	Cathodic protection and coatings *See* Note 4
	Boot topping and splash zones *See* Note 3	Legs	Coatings
	Atmospheric zone	All structure above the splash zone	Coatings only
Surface type units	Submerged zone	Main hull	Cathodic protection or coatings *See* Note 1
	Boot topping and splash zones	Main hull	Coatings
	Atmospheric zone	All structure above the splash zone	Coatings only

NOTES
1. For the assignment of the In-water Survey notation **OIWS,** corrosion protection by both cathodic protection and high resistance paint coatings is required.
3. For column-stabilised units, the boot topping zone is to be taken as that part of the external structure between the maximum design operating draught and the transit draught.
3. For self-elevating units, in the elevated position, the boot topping zone is to extend between the lowest and highest atmospheric tides at the operating location.
4. If In-water Survey notation, **OIWS** is not assigned, then coatings may be omitted except in the boot topping zone, *see* Note 2.

1.2.6 **Internal zones**. Ballast tanks, liquid storage tanks, and other compartments.

1.3 External zone protection

1.3.1 The minimum requirements for corrosion protection of the external steelwork of offshore units is given in Table 1.1.1.

1.3.2 The structural steelwork in the boot topping and splash zones is normally to be protected by suitable coatings but consideration may be given to the following:

(a) Extra steel in excess of the Rule requirements.

(b) Metallic cladding where appropriate.

1.3.3 The structural steelwork in the atmospheric zone is to be protected by suitable coatings.

1.3.4 The structural steelwork in the submerged zone is to be protected by an approved means of cathodic protection using sacrificial anodes or an impressed current system, except where noted otherwise in Table 1.1.1. High resistance coatings may be required or used in conjunction with a cathodic protection system but they will not be accepted in lieu of cathodic protection except where noted in Table 1.1.1. An alternative means of protection such as increased scantlings may be considered in special areas.

1.4 Internal zones

1.4.1 Ballast tanks shall be protected from corrosion by a combination of anti-corrosion coatings and cathodic protection.

1.4.2 At the time of new construction, all salt-water ballast tanks shall have an efficient protective coating, epoxy or equivalent, applied in accordance with the manufacturer's recommendations. The durability of the coatings could affect the frequency of survey of the tanks and light coloured coatings would assist in improving the effectiveness of subsequent surveys. It is therefore recommended that this be taken into account by those agreeing the specification for the coatings and their application.

1.4.3 Storage tanks and other compartments require corrosion protection where the storage product may be corrosive. Particular attention should be paid to the likelihood of water in the bottom of hydrocarbon storage tanks and the effects of bacterially induced corrosion. Suitable protective measures may include coatings, corrosion inhibitors, together with biocides.

1.4.4. In deep draught caisson units and other units with combined oil storage and ballast tanks which remain full during the service life of the unit, special consideration will be given to the requirement for internal corrosion protection of the tanks. In general, the minimum Rule scantlings of tanks as required by Pt 4, Ch 6,7 are to be suitably increased.

1.5 Bimetallic connections

1.5.1 Where bimetallic connections are made in the structure, suitable measures are to be incorporated to preclude galvanic corrosion. Details are to be submitted for approval on the structural plans required in Pt 4, Ch 1,4. The combination of painting the less noble material and leaving the more noble material uncoated for an immersed bimetallic couple is not permitted.

1.6 Chain cables and wire ropes

1.6.1 Chain cables and wire ropes for positional mooring systems are to be protected from corrosion and the requirements of Pt 3, Ch 10 are to be complied with.

■ *Section 2* Riser systems

2.1 General

2.1.1 When riser systems are fitted in accordance with Pt 3, Ch 12 the risers are to be suitably protected against corrosion. It is recommended that this be achieved using a coating combined with a cathodic protection system. Account should be taken of possible temperature effects. Other equivalent methods of protection will be considered.

2.1.2 The splash and boot topping zones of risers are to be specially considered. A corrosion allowance will be required in addition to any coatings. Risers in J-tubes, etc., will require separate assessment of protection.

2.1.3 Where the cathodic protection system is designed to compensate for loss of protective coating, the system should be based on an initial loss of coating of between 5 and 10 per cent. Due allowance should be made for further breakdown during the service life.

2.2 External coatings

2.2.1 Paint or protective coatings are generally to be chosen in conjunction with the system of cathodic protection.

2.2.2 The performance of the coating materials used should be proven by previous service or by extensive and documented laboratory testing.

2.2.3 Preparation of the riser surface before coating is to comply with the approved specification relating to that material, *see* Ch 4,3.5.

2.3 Internal protection

2.3.1 The method of internal protection is to take into account the corrosivity, bacterial content, solids/abrasive content, flow characteristics and temperature and pressure.

2.3.2 Materials or systems (e.g., liners) are to be evaluated against the service nature of the product to be conveyed. Proprietary specifications and in-service history are to be submitted as required by LR.

2.3.3 Where internal protection is proposed by use of corrosion inhibitors, the properties, compatibility and effect on product conveyed are all to be documented and submitted.

2.4 Cathodic protection systems

2.4.1 Cathodic protection systems are to comply with the requirements of Chapter 2.

2.4.2 Measurements of potential are to be taken and any deficiencies corrected by the addition of extra sacrificial anodes.

2.4.3 Measurements are to be taken to confirm that there is no over-protection.

2.4.4 Stray currents from ships, other vessels or installations in the vicinity are to be evaluated and appropriate measures taken.

■ *Section 3* Plans and information

3.1 Scope

3.1.1 In order that an assessment may be made of protection systems full details as outlined in this Section are to be submitted.

3.2 Cathodic protection systems

3.2.1 The following plans and information are to be submitted:

(a) A surface area breakdown for all areas to be protected including secondary steelwork and details of appurtenances.
(b) The resistivity of the sea-water.
(c) All current densities used for design purposes.
(d) The type and location of any reference electrodes and their methods of attachment.
(e) Full details of any coatings used and the areas to which they are to be applied.
(f) Details of any electrical bonding.

3.3 Sacrificial anode systems

3.3.1 In addition to the information required by 3.2 the following plans and information are to be submitted:

(a) The design life of the system in years.
(b) Anode material and minimum design capacity of anode material, in Ah/kg.
(c) The dimensions of anodes including details of the insert and its location.
(d) The net and gross weight of the anodes, in kg.
(e) The means of attachment.
(f) Plans showing the location of the anodes.
(g) Calculation of anodic resistance, as installed and when consumed to their design and utilisation factor, in ohms.
(h) Closed circuit potential of the anode material, in volts.
(j) Details of any computer modelling.
(k) The anode design utilisation factor.

3.4 Impressed current systems

3.4.1 In addition to the information required by 3.2, the following plans and information are to be submitted:

(a) The anode composition and where applicable the thickness of the plated surface, consumption and life data.
(b) Anode resistance, limiting potential and current output.
(c) Details of construction and attachment of anodes and reference electrodes.
(d) Size, shape and composition of any dielectric shields.
(e) Diagram of the wiring system used for the impressed current and monitoring systems including details of cable sizes, underwater joints, type of insulation and normal working current in circuits, and the capacity, type and make of the protected devices.
(f) Details of glands and size of steel conduits.
(g) Plans showing the locations of the anodes and reference electrodes.
(h) If the system is to be used in association with a coating system then a statement is to be supplied by the coating manufacturer that the coating is compatible with the impressed current cathodic protection system.

3.5 Coating systems

3.5.1 The following plans and information are to be submitted:

(a) Evidence that any primers used will have no deleterious effect on subsequent welding or on subsequent coatings.
(b) Details of the painting specification with regard to:
    (i) the generic type of the coating and confirmation of its suitability for the intended environment;
    (ii) the methods to be used to prepare the surface before the coating is applied and the standard to be achieved. Reference should be made to established International or National Standards;
    (iii) the method of application of the coating; and
    (iv) the number of coats to be applied and the total dry film thickness.
(c) Details of the areas to be coated.

3.5.2 In addition to the information required by 3.5.1 the following may also be required:

(a) When a coating contains aluminium and is intended to be used on decks or in areas where flammable gases may accumulate, a statement from an independent laboratory confirming that appropriate tests have shown that the coating does not increase the incendive sparking hazard in the area to which it is to be applied.

(b) Where a coating is to be applied in accommodation spaces, machinery spaces and areas of similar fire risk, a statement that the coating is not formulated on a nitrocellulose or other highly flammable base and has low flame spread characteristics (complying to at least BS476: Part 7: Classification 2 or any other equivalent National Specification).

3.6 Inhibitors and biocides

3.6.1 Where it is proposed to use inhibitors, biocides, or other chemicals for the protection of storage tanks, full details, including compatibility with each other and evidence of satisfactory service experience or suitable laboratory test results or any other data to substantiate the suitability for the intended purpose, are to be submitted for consideration.

■ *Section 1* General requirements

1.1 Objective

1.1.1 The cathodic protection system for the external submerged zone is to be designed for a period commensurate with the design life of the structure or the dry-docking interval and it should be capable of polarising the steelwork to a sufficient level in order to minimise corrosion.

1.1.2 This may be achieved using either sacrificial anodes or an impressed current system or a combination of both, *see* 3.2.1.

1.2 Electrical continuity

1.2.1 All parts of the structure should be electrically continuous and where considered necessary, appropriate bonding straps should be fitted across such items as propellers, thrusters, rudders and legs, etc., and the joints of articulated structures are to be efficiently completed to the Surveyor's satisfaction.

1.2.2 Where bonding straps are not fitted, a supplementary cathodic protection system should be considered.

1.2.3 Particular attention to earthing and bonding is required in hazardous areas where flammable gases or vapours may be present, *see* Part 7.
To avoid dangerous sparking between metallic parts of structures, potential equalisation is always required for installations in Zone 1 and may be necessary for installations in Zone 2 Areas; this is achieved by connecting all exposed and extraneous conductive parts to the equipotential bonding system. Notwithstanding this, cathodic protection installations shall not be connected to the equipotential bonding system unless the cathodic protection system is specifically designed for this purpose. *See* IEC 61892-7 Section 5.6.3.
Cathodically protected metallic parts are live extraneous conductive parts. If located in hazardous areas, they shall be considered potentially dangerous (especially if equipped with the impressed current method) despite their low negative potential.
No cathodic protection shall be provided for metallic parts in Zone 0 unless it is specially designed for this application. *See* IEC 61892-7 Section 5.6.6.

1.2.4 Consideration should be given to the influence of any connecting structures, such as risers and pipelines, on the efficiency of the cathodic protection system. A floating structure may be permanently or temporarily connected to another neighbouring structure. In this situation, the requirements of BS EN 13173 shall be met, including the taking of measurements to ensure that there are no deleterious effects of electrical stray current on the protected structure.

1.3 Criteria for cathodic protection

1.3.1 Cathodic protection systems shall comply with BS EN 13173 - *Cathodic protection for steel offshore floating structures* or BS EN 12495 - *Cathodic protection for fixed steel offshore structures*.

1.3.2 The cathodic protection system is to be capable of polarising the steelwork to potentials measured with respect to a silver/silver chloride/sea-water (Ag/AgCl) reference electrode to within the following ranges:
(a) –0,80 to –1,10 volts for aerobic conditions.
(b) –0,9 to –1,10 volts for anaerobic conditions.

1.3.3 Potentials more negative than –1,10 volts Ag/AgCl must be avoided in order to minimise any damage due to hydrogen absorption and reduction in the fatigue life. For steel with a tensile strength in excess of 700 N/mm^2 the maximum negative potential should be limited to –0,95 volt. But where the steel is prone to hydrogen-assisted cracking the potential should not be more negative than –0,83 volt (Ag/AgCl reference cell).

1.3.4 High strength fastening materials should be avoided because of the possible effects of hydrogen, and the hardness of such bolting materials should be limited to a maximum of 300 Vickers Diamond Pyramid Number.

1.3.5 The potential for steels with surfaces operating above 25°C should be 1 mV more negative for each degree above 25°C.

1.3.6 For guidance on the design of sacrificial anode systems, *see* Ch 4,2.

■ *Section 2* Sacrificial anodes

2.1 General

2.1.1 Sacrificial anodes intended for installation on offshore units are to be manufactured in accordance with the requirements of this Section.

2.1.2 Plans showing anode nominal dimensions, tolerances and fabrication details are to be submitted for approval prior to manufacture.

2.1.3 Approval for the manufacture of anodes is not required although the anodes should preferably be type approved in accordance with LR's *List of Type Approval Equipment*.

2.1.4 The works should have a quality management system certified by a recognised third party certification body. However, alternative arrangements may be accepted provided they ensure a consistent quality for the anodes.

2.2 Anode materials

2.2.1 The anode materials are to be approved alloys of zinc or aluminium with a closed circuit potential of at least –1,00 volt (Ag/AgCl reference electrode). Magnesium-based anodes may be used for short-term temporary protection of materials not susceptible to hydrogen embrittlement, *see also* 2.13.12. Anode materials and anode designs specified in BS EN 13173 or BS EN 12495 are also permitted.

2.3 Steel insert preparation

2.3.1 The anode material is to be cast around a steel insert so designed as to retain the anode material even when it is consumed to its design utilisation factor.

2.3.2 The steel inserts are to have sufficient strength to withstand all external forces that they may normally encounter such as wave, wind, ice loading and operating conditions.

2.3.3 The anodes are to be sufficiently rigid to avoid vibration in the anode support.

2.3.4 The steel inserts are to be of weldable structural steel bar, section or pipe with a carbon equivalent not greater than 0,45 per cent determined using the following formula.

Carbon equivalent, $C_{eq} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$

Rimming steel is not permitted.

2.3.5 Requirements for welded fabrication and non-destructive testing are to be in accordance with Chapter 13 of the Rules for Materials.

2.3.6 The steel insert is to be degreased if necessary and blast cleaned to a standard equivalent to ISO 8501-1 Sa $2^1/_2$ with a minimum surface profile of 50 μm. This standard of cleanliness is to be maintained up until the time of castings. For zinc anodes, blast cleaning may be followed by galvanising or by an approved zinc plating process.

2.4 Chemical composition

2.4.1 The chemical composition of the heat is to be determined prior to casting. No alloying additions are to be made following chemical analysis without further analysis. For heats greater than 1 tonne, a further sample is to be analysed at the end of the cast. All anodes cast are to comply with the approved specification.

2.5 Conditions of supply

2.5.1 Generally anodes are to be supplied in the as-cast condition although certain aluminium anodes may be heat treated in accordance with the approved specification.

2.5.2 Where heat treatment is carried out, it is to be in properly constructed furnaces which are efficiently maintained and have adequate means for the control and recording of temperature. The furnace dimensions are to be such as to allow the whole item to be uniformly heated to the necessary temperature.

2.6 Anode identification

2.6.1 The manufacturer is to adopt a system of identification of the anodes to enable the material to be traced back to its original cast.

2.6.2 The anodes are to be clearly marked with the following:

(a) Name or initials of the anode manufacturer.
(b) Number and/or initials to identify the batch.
(c) Agreed identification mark for the anode material.

2.6.3 Where the anodes are heat treated they are also to be marked with the appropriate heat treatment batch number.

2.7 Anode inspection

2.7.1 All anodes are to be cleaned and adequately prepared for inspection. The surfaces are not to be hammered, peened or treated in any way which may obscure defects. However, any flash or other protrusions should be removed prior to inspection.

2.7.2 Anodes are to be inspected prior to the application of any coating which may be applied to the underside of the anode or to the exposed steelwork.

2.7.3 The surface should be free of any significant slag or dross or anything that may be considered detrimental to the satisfactory performance of the anodes.

2.7.4 Shrinkage depressions should not exceed the smaller of 10 per cent of the nominal depth of the anode or 50 per cent of the depth to the anode insert.

2.7.5 Cracks in the longitudinal direction are not acceptable. Small transverse cracks may be permitted provided:
(a) they are not more than 5 mm in width,
(b) they are within the section wholly supported by the steel insert,
(c) they do not extend around more than two faces or 180° of the anode circumference, and
(d) the Surveyor is satisfied that there has been no break-down in Quality Control procedures.

2.7.6 Cold shuts or surface laps should not exceed a depth of 10 mm or extend over a total length equivalent to more than three times the width of the anode. All material is to be completely bonded to the bulk material.

2.8 Dimensions

2.8.1 The accuracy and verification of dimensions is the responsibility of the manufacturer unless otherwise agreed.

2.8.2 The diameter of cylindrical anodes should be within ±5 per cent of the nominal diameter.

2.8.3 For long slender anodes the following dimensions should apply:
(a) Mean length ±3 per cent of nominal length or ±25 mm whichever is smaller.
(b) Mean width ±5 per cent of nominal width.
(c) Mean depth ±10 per cent of nominal depth.

2.8.4 The maximum deviation from straightness should not exceed two per cent of the length.

2.8.5 The steel insert should be within ±5 per cent of the nominal position in anode width and length and within 10 per cent of the nominal position in depth. Some anodes may have the insert close to one surface, in which case a closer tolerance may be more appropriate.

2.8.6 Except where previously agreed, the anode insert fixing dimensions are to be within ±1 per cent of the nominal dimensions or 15 mm, whichever is the smaller.

2.8.7 Anode nominal dimensions, tolerances and fabrication details are to be shown on manufacturing plans prepared by the manufacturer and submitted for approval, *see* Ch 1,3.3.

2.9 Anode weight

2.9.1 Anodes are to be weighed and individual anodes should be within ±5 per cent of the nominal weight for anodes less than 50 kg or ±3 per cent of the nominal weight for anodes 50 kg and over.

2.9.2 No negative tolerance is permitted on the total contract weight and the positive tolerance should be limited to two per cent of the nominal contract weight.

2.10 Bonding and internal defects

2.10.1 It will be necessary for the manufacturer to demonstrate that there is a satisfactory bond between anode material and the steel insert and that there are no significant internal defects. This may be carried out by sectioning of an anode selected at random from the batch or by other approved means.

2.10.2 Where sectioning is carried out, at least one anode or at least 0,5 per cent of each production run is to be sectioned transversely at 25 per cent, 33 per cent and 50 per cent of the nominal length of the anode or at other agreed locations for a particular anode design.

2.10.3 The cut surfaces are to be essentially free from slag or dross.

2.10.4 Small isolated gas holes and porosity may be accepted, provided their surface area is not greater than two per cent of the section.

2.10.5 No section is to show more than 10 per cent lack of bond between the insert and the anode material.

2.11 Electrochemical testing

2.11.1 Electrochemical performance testing is to be carried out by the manufacturer in accordance with previously approved procedures designed to demonstrate batch consistency of the as-cast electrochemical properties.

2.12 Certification

2.12.1 The manufacturer is to provide copies of the Material Certificate or shipping statement for all acceptable anodes.

2.12.2 The certificate is to include at least the following information:
(a) Name of manufacturer.
(b) Description of anode, alloy designation or trade name.
(c) Cast identification number.
(d) Chemical composition.
(e) Details of heat treatment where applicable.
(f) Results of electrochemical test.
(g) Weight data.
(h) Purchaser's name and order number, and the name of the structure for which the material is intended.

2.12.3 The manufacturer is to confirm that the tests have been carried out with satisfactory results in accordance with the approved specification and the Rules.

2.13 Anode installation

2.13.1 The location and means of attachment of anodes is to be submitted for approval.

2.13.2 The anodes are to be attached to the structure in such a manner that they remain secure throughout the service life.

2.13.3 Where bracelet anodes are proposed, the tightness of the anodes are not to rely on the anode material being in direct contact with the structure.

2.13.4 The location and attachment of anodes is to take account of the stresses in the members concerned. Anodes are not to be directly attached to the shell plating of main hull columns or primary bracings.

2.13.5 The anode supports may be welded directly to the structure in low stress regions provided they are not attached in way of butts, seams, nodes or any stress raisers. They are not to be attached to separate members which are capable of relative movement.

2.13.6 The attachment of all anodes to primary bracing members and nodes is to be submitted for approval. Anodes are not to be welded directly to the structure and the supports are to be welded to small doubler plates which are attached by continuous welds to the structure.

2.13.7 All welding is to be carried out by qualified welders using a qualified welding procedure in accordance with Chapters 12 and 13 of the Rules for Materials.

2.13.8 The welds are to be examined using magnetic particle inspection or other acceptable means of non-destructive testing in accordance with Chapter 13 of the Rules for Materials.

2.13.9 Anodes attached to studs 'fired' into the structure are not permitted.

2.13.10 The anodes are to be located on the structure to ensure rapid polarisation of highly stressed areas such as node welds and with due regard to a possible reduction in throwing power in re-entrant angles.

2.13.11 Anodes should not be located in positions where they may be damaged by craft coming alongside.

2.13.12 Magnesium anodes are not to be used in way of higher tensile steel or coatings which may be damaged by the high negative potentials unless suitable dielectric shields are fitted, *see* 2.2.1.

■ *Section 3*
Impressed current anode systems

3.1 General

3.1.1 Impressed current anode materials may be of lead-silver alloy or platinum over such substrates as titanium, niobium, tantalum, or of mixed oxides-activated titanium. Anode materials and anode designs specified in BS EN 13173 or BS EN 12495 are also permitted.

3.1.2 The design and installation of electrical equipment and cables is to be in accordance with the requirements of Pt 6, Ch 2.
If hazardous areas are present on the facility, the impressed current cathodic protection system and equipment shall comply with the requirements of: Pt 6, Ch 2 (in particular Section 5.1.3), Pt 7, Ch 2,8, 9, 10 and 11, IEC 60079 series and IEC 60092-502.
IEC 60092-502 Clause 5.7 'Cathodically protected metallic parts' states 'No impressed current cathodic protection shall be provided for metallic parts in hazardous areas, unless it is specially designed for this application and acceptable to the appropriate authority'.
The insulating elements required for the cathodic protection, for example, insulating elements in pipes and tracks, should if possible be located outside the hazardous area. *See* IEC 61892-7 Section 5.6.6.

3.1.3 All equipment is to be suitable for its intended location. Cables to anodes are not to be led through tanks intended for the storage of low flash point oils. Where cables are led through cofferdams of oil storage units they are to be enclosed in a substantial steel tube of about 10 mm thickness.

3.1.4 The arrangement for glands, where cables pass through shell boundaries, are to include a small cofferdam.

3.1.5 Cable and insulating material should be resistant to chloride, hydrocarbons and any other chemicals with which they may come into contact.

3.1.6 The electrical connection between the anode cable and the anode body is to be watertight and mechanically and electrically sound.

3.1.7 Where the power is derived from a rectified a.c. source, adequate protection is to be provided to trip the supply in the event of:
(a) a fault between the input or high voltage windings of the transformer (i.e., main voltage) and the d.c. output of the associated rectifier; or
(b) the ripple on the rectified d.c. exceeding five per cent.
The requirements for transformers and semi-conductor equipment are given in Pt 6, Ch 2,9.

3.1.8 Anodes may be installed by mounting in insulating holders attached directly to the submerged structural member, provided the general requirements given in 2.13 regarding attachments to the structure are complied with.

3.1.9 Suitable dielectric shields are to be fitted in order to avoid high negative potentials.

3.1.10 A warning light or other warning indicator is to be arranged at the control position from which divers are controlled to indicate that the impressed current cathodic protection system has been switched off when divers are in the water.

3.2 Protection after launching and during outfitting

3.2.1 Where protection is primarily by an impressed current cathodic protection system, sufficient sacrificial anodes are to be fitted, capable of polarising the critical regions of the structure from the time of initial immersion until full commissioning of the impressed current system.

■ *Section 4* Fixed potential monitoring systems

4.1 General

4.1.1 A permanent monitoring system is to be installed on structures protected by an impressed current cathodic protection system, and, although not essential, such a monitoring system is recommended for use in conjunction with sacrificial anodes. Monitoring schemes shall comply with BS EN 13509 – *Cathodic protection measurement techniques*.

4.1.2 Zinc or Ag/AgCl reference electrodes should be used. Reference electrode materials and design specified in the above standard are also permitted.

4.1.3 The location and attachment of the reference electrodes is to take account of the stresses in the members concerned and they should not be attached in highly stressed areas or in way of butts, seams, nodes or any stress raisers.

4.1.4 The location of the reference electrodes should be such as to enable the performance of the cathodic protection system to be adequately monitored.

4.1.5 The reference electrodes may be connected to the topside display and control equipment by suitable cabling or by any other agreed means.

4.1.6 Provision is to be made for the regular recording at an agreed interval of the potential of the steelwork and log sheets are to be made available for inspection when required by LR Surveyors.

■ *Section 5* Cathodic protection in tanks

5.1 General

5.1.1 Impressed current cathodic protection systems are not to be fitted in any tank.

5.2 Sacrificial anodes

5.2.1 Particular attention is to be given to the locations of anodes in tanks that can contain explosive or other inflammable vapour, both in relation to the structural arrangements and openings of the tanks.

5.2.2 Aluminium and aluminium alloy anodes are permitted in tanks that may contain explosive or flammable vapour, or in ballast tanks adjacent to tanks that may contain explosive or flammable vapour, but only at locations where the potential energy of the anode does not exceed 275 J (28 kgfm). The weight of the anode is to be taken as the weight at the time of installation, including any inserts and fitting devices. The height is to be taken as the distance from the bottom of the tank to the centre of the anode, but exception to this may be given where the anodes are located on wide horizontal surfaces from which they cannot fall.

5.2.3 Aluminium anodes are not to be located under tank hatches or other openings unless protected by adjacent structure.

5.2.4 Magnesium or magnesium alloy anodes are permitted only in tanks intended solely for water ballast, in which case adequate venting must be provided.

5.2.5 Anodes fitted internally should preferably be attached to stiffeners, or aligned in way of stiffeners on plane bulkhead plating. Where they are welded to assymetrical stiffeners, they are to be connected to the web with the welding at least 25 mm away from the edge of the web.

5.2.6 In the case of stiffeners or girders with symmetrical face plates, the connection may be made to the web or to the centreline of the mild steel face plate but well clear of the free edges. Where higher tensile steel face plates are fitted the anodes are to be attached to the webs.

5.2.7 Anodes are not to be attached directly to the shell plating of main hulls, columns or primary bracings.

5.2.8 For guidance on the design of sacrificial anode systems in tanks, *see* Ch 4,2.

Section 6
Potential surveys

6.1 General

6.1.1 Potential surveys of the external submerged zones are to be carried out at agreed intervals, *see also* Pt 1, Ch 3.

6.1.2 Should the results of any potential survey measured with respect to a Ag/AgCl reference cell indicate values more positive than –0,8 volt for aerobic conditions or –0,9 volt for anaerobic conditions then remedial action is to be carried out at the earliest opportunity.

Section 7
Retrofits

7.1 General

7.1.1 Where it is proposed to fit additional anodes or replace existing ones then full details are to be submitted for consideration.

7.1.2 Where it is necessary to weld anodes to the structure then only approved welding procedures and consumables are to be used in accordance with Chapters 12 and 13 of the Rules for Materials.

Section

■ *Section 1* General requirements

1.1 General

1.1.1 The painting specification is to be submitted for approval, *see* Ch 1,3.5.1.

1.1.2 Paints, varnishes and similar preparations having nitrocellulose or other highly flammable base are not to be used in accommodation or machinery spaces or in other areas with an equal or higher fire-risk.

1.1.3 Where a coating is to be applied in accommodation spaces and areas of similar fire-risk, the coating is to have low flame spread characteristics, *see* Ch 1,3.5.2(b).

1.1.4 Paints or other similar coatings containing aluminium should not be used in positions where flammable vapours may accumulate, unless it has been shown by appropriate tests that the paint to be used does not increase the incendive sparking hazard.

1.1.5 Any sheathing or composition to protect decks is to be applied in such a manner that corrosion will not occur unseen beneath the covering.

1.1.6 Deck coatings or coverings used on decks forming the crown of spaces with a high fire-risk (such as helidecks, machinery and accommodation spaces) or which are within accommodation spaces, control rooms, emergency escape routes, etc., are to be of a type which will not readily ignite, *see* Ch 1,3.5.2(b).

1.1.7 Paints or other coatings are to be suitable for the intended purpose in the locations where they are to be used.

1.1.8 Coatings are to be applied to blast cleaned surfaces prepared to at least an equivalent of ISO 8501-1 Sa $2^1/_2$. All resulting dust is to be removed from the surface prior to the application of any paint.

1.1.9 The selection, application and maintenance of coatings for dedicated sea-water ballast tanks (including pre-load tanks on self-elevating units), double-side skin spaces, etc., shall also comply with IMO Resolution MSC.215(82), *Performance Standards for Protective Coatings*. All dedicated sea-water ballast tanks and double-side skin spaces are to comply with all of the requirements of the Resolution.

1.1.10 Maintenance of the protective coating systems shall be included in the unit's overall maintenance scheme.

1.1.11 The paint (and/or primer) used on the inner hull of some LNG containment systems (particularly membrane type) requires the use of a suitable paint system to provide adhesion of the containment system (via a curing mastic) to the inner hull, in accordance with the designer's specification, as approved by LR.

■ *Section 2* Prefabrication primers

2.1 General

2.1.1 Where a primer is used to coat steel after surface preparation and prior to fabrication, the composition of the coating is to be such that it will have no significant deleterious effect on subsequent welding work and that it is compatible with the paints or other coatings subsequently applied.

2.1.2 To determine the influence of the primer coating on the characteristics of welds, tests are to be made as detailed in 2.1.3 to 2.1.5. *See* LR's *List of Paint Resins, Reinforcements and Associated Materials*.

2.1.3 Three butt weld assemblies are to be tested using plate material 20 to 25 mm thick. A vee preparation is to be used and prior to welding, the surfaces and edges are to be treated as follows:

(a) Assembly 1 – Coated in accordance with the manufacturer's instructions.
(b) Assembly 2 – Coated to a thickness approximately twice the manufacturer's instructions.
(c) Assembly 3 – Uncoated.

2.1.4 Tests as follows are to be taken from each test assembly:

(a) **Radiographs**. These are to have a sensitivity of better than two per cent of the plate thickness under examination, as shown by an image quality indicator.
(b) **Photo-macrographs**. These may be of actual size and are to be taken from near each end and from the centre of the weld.
(c) **Face and reverse bend test**. The test specimens are to be bent by pressure or hammer blows round a former of diameter equal to three times the plate thickness.
(d) **Impact tests**. Tests are to be carried out, at ambient temperature, on three Charpy V-notch test specimens prepared in accordance with the requirements of the Rules for Materials. The specimens are to be notched at the centreline of the weld, perpendicular to the plate surface.

2.1.5 The tests are to be carried out in the presence of an LR Surveyor or by an independent laboratory specialising in such work. A copy of the test report is to be submitted, together with radiographs and macrographs.

Section

Section 1 External steel protection

1.1 Current density

1.1.1 The current density required for the external protection of the submerged zone of mobile offshore units will depend on many factors such as water temperature, oxygen content, resistivity of the water, suspended solids, water currents and biological activity.

1.1.2 Design current density values are given in Table 4.1.1 for guidance purposes, but the values to be used should be based on the environmental conditions prevailing at the site. It should be noted that these values may be appreciably different from values actually measured on steelwork in the vicinity of the site.

1.1.3 In order to minimise pitting, the cathodic protection system must be capable of rapidly polarising the steelwork and it is recommended that the initial current density should be appreciably higher than the values given in Table 4.1.1.

1.1.4 Although a lower current density may be capable of maintaining polarisation, the cathodic protection system must be capable of re-polarising the steelwork rapidly after storms even when the anodes are well wasted.

1.1.5 Where suitable high resistance coatings are used consideration will be given to use of current densities lower than those given in Table 4.1.1.

1.1.6 Coatings will deteriorate with time and there is likely to be mechanical damage. In order to take this into account at the design stage, appropriate coating breakdown factors should be applied and these are to be based on the percentages given in 1.1.7.

1.1.7 For an epoxy or coal tar epoxy coating applied to give a dry film thickness of 250 to 500 microns, an initial coating breakdown of one to two per cent for the submerged zone and an annual degradation rate of one to three per cent per year should be used.

1.2 Sacrificial anode systems

1.2.1 The following indicates an acceptable method for determining the number and weight of anodes to achieve the required level of polarisation on most structures. Other methods may be accepted provided they give reasonable equivalence.

Table 4.1.1 Current density values for design purposes

Location		Current density mA/m^2
Cook inlet		400
North Sea (Northern)	Above 62°N 55°N to 62°N	130 120
US (West Coast)		100
North Sea (Southern) Africa Brazil China India Mediterranean	Below 55°N	90 90 90 90 90 90
Australia (Western) Gulf Gulf of Mexico		80 80 80
Mud – Most locations		20
Drainage per well		5A

NOTES
1. The current density values are intended for guidance purposes in the design of sacrificial anode systems using the methods as outlined in this Chapter. However, other values may be accepted provided that there is adequate justification.
2. For impressed current cathodic protection systems, current densities higher than the values given in the Table may be necessary but this will depend on the type and location of the anodes.

1.2.2 The type of anode selected must be of sufficient mass with appropriate dimensions to ensure an adequate current output throughout its design life.

1.2.3 The current output of the anode should be calculated using the following formula:

$$I_a = \frac{\Delta V}{R_a}$$

where

I_a = current output of anode, in amps

ΔV = driving potential, i.e., the difference between the potential of the anode and the protected steel potential, in volts

R_a = anodic resistance, in ohms.

1.2.4 The potential of the polarised steel should be taken as –0,8 volt (Ag/AgCl/sea-water reference electrode), although a more negative value may be used for those locations where sulphate reducing bacteria may be active, *see* Ch 2,1.3.

1.2.5 The resistance of an anode, *R*, with small cross-section in relation to its length and with a stand-off distance from the bottom of the anode surface to the structure of not less than 300 mm, is given by:

(a) $$R = \frac{\rho}{2\pi\, l_a}\left(l_n \frac{4l_a}{r} - 1\right)$$

where

ρ = resistivity of sea-water, in ohm.cm

l_a = length of anode, in cm

r = equivalent radius of anode, in cm

l_n = $\log_e$

$$r = \sqrt{\frac{a}{\pi}}$$

a = cross-sectional area of the anode, in cm^2

(b) When bracelet anodes are used, the resistance may be determined using:

$$R = \frac{0{,}315\rho}{\sqrt{A_e}}$$

where

A_e = the exposed surface area of the anode, in cm^2.

1.2.6 In order to achieve a suitable anode distribution on tubular structures, each appropriate section of steelwork should be considered separately.

1.2.7 The current required for each section may be determined from the following:

$$I_r = \frac{A\, I}{1000}$$

where

I_r = current, in amps

A = area of steelwork, in m^2

I = current density, in mA/m^2.

1.2.8 The number of anodes, *N*, required should satisfy both of the following:

(a) $$N = \frac{I_r}{I_a}$$

(b) $$N = \frac{W_r}{W_a}$$

where

I_r = current, in amps

I_a = current output of anode, in amps

W_r = net weight of anode material, in kg

W_a = net weight of individual anode, in kg

$$W_r = \frac{I_r\, Y\, 8760}{CU}$$

Y = life of structure or appropriate dry-docking interval in years, *see* Ch 2,1.1.1

C = practical electrochemical capacity of the alloy, in Ah/kg

U = utilisation factor, i.e., proportion of net weight consumed at end of anode life. For fully supported tubular inserts

U = 0,9

U = 0,8 for bracelet (half shell)

U = 0,75 for bracelet (segmental type).

In order to optimise the performance and efficiency of the anodes, the values for both equations should be similar.

1.2.9 It is to be shown by appropriate calculations that the system is capable of polarising the structure initially and also when the anodes are consumed to their design utilisation factor.

1.2.10 It should be assumed that, at the end of its life, the anode length has been reduced by 10 per cent and that the remaining material is evenly distributed over the steel insert.

1.3 Location of anodes

1.3.1 Having determined the number and size of the anodes to comply with the recommended nominal current density and the required life, the anodes should be distributed over the steel surfaces according to the required level of protection on the steelwork but with some emphasis on the area adjacent to joints, etc. The anodes associated with the structure likely to become buried, such as footings, etc., should be positioned on the steelwork immediately above the mudline.

■ *Section 2* Protection of tanks

2.1 Anode resistance

2.1.1 Where large stand-off anodes are used for the protection of tanks, the resistance should be determined using the formula as given in 1.2.5(a).

2.1.2 Where flat plate anodes are used, their resistance is to be determined from the following formula:

$$R = \frac{\rho}{4l_m}$$

however, if the flat plate anodes are close to the structure or painted on the lower face then the resistance is to be determined using:

$$R = \frac{\rho}{2l_m}$$

where ρ is as defined in 1.2.5

l_m = mean length of anode sides, in cm.

2.2 Current density

2.2.1 The design current density to be used for permanent water ballast tanks should be based on a minimum value of 110 mA/m^2 but this may have to be increased to at least 130 mA/m^2 if hot oil is stored on the opposite side of the bulkhead. For a coating allowance, *see* 1.1.6.

2.2.2 Uncoated tanks used for the storage of crude oil at ambient temperature alternating with water ballast are to have a minimum current density of 90 mA/m^2; however, this should be increased for higher temperatures.

2.2.3 Unless otherwise agreed the resistivity of the water in ballast tanks should be assumed to be 25 ohm.cm.

2.3 Anode distribution

2.3.1 Once the number and size of anodes have been determined, they are to be distributed as follows:

(a) **Ballast only tanks**: evenly over all the steelwork.
(b) **Crude oil/ballast tanks**: evenly but with some emphasis on horizontal surfaces in proportion to the area of these surfaces.

2.4 Reference electrodes

2.4.1 Variations between electrodes of ±30 mV have been reported for zinc/sea-water reference electrodes and ±5 mV for silver/silver chloride/sea-water electrodes but unless a high degree of stability is required either electrode may be used for comparison purposes. The zinc/sea-water electrode may be taken as approximately 1,03 V more positive than the silver/silver chloride/sea-water electrode.

■ *Section 3* Surface preparation, application and maintenance of coatings

3.1 Application

3.1.1 These notes have been prepared to give general guidance on those aspects of surface preparation and application and the subsequent maintenance of coatings that should be taken into account by those agreeing the coating specification.

3.1.2 These notes are not intended to be used for contractual purposes or as representing the minimum requirements as these are a matter for the interested parties to agree.

3.1.3 The guidelines do not intend to replace the technical aspects of any specific coating system, to be covered by the product and job specifications, which are at the discretion and under the responsibility of Owners, manufacturers and construction yards.

3.1.4 Owners should select and maintain a corrosion protection system to ensure an adequate level of protection.

3.1.5 Coating manufacturers should give evidence of the quality of the product and its ability to satisfy the Owner's requirements.

3.1.6 Coating manufacturers should have products with documented service performance records. Coatings recognised by Lloyd's Register (hereinafter referred to as LR) are considered as satisfying this requirement, *see* list of LR approved PSPC compliant coatings on CDLive. Where it is proposed to use coatings without satisfactory performance records, coating selection should be supported by appropriate laboratory test data carried out in accordance with recognised Standards (e.g., ISO 20340) in order to verify their suitability for the intended service condition.

3.1.7 The construction yard and/or its subcontractors should provide clear evidence of their experience in coating application. The coating Standard, job specification, inspection, maintenance and repair criteria should be agreed by the construction yard and/or its subcontractors, Owner and manufacturer.

3.2 General requirements

3.2.1 At present, hard coatings are the most commonly used for new construction.

3.2.2 As their effectiveness and life are influenced by several factors it is essential that the manufacturer's technical product data sheet and job specifications are followed.

3.2.3 Multi-coat applications with coating layers of contrasting colours are recommended. The last coating layer in ballast tanks should be of a light colour in order to facilitate in-service inspections.

3.2.4 Measures should be adopted at the design stage to reduce scallops, using rolled profiles (provided this does not adversely affect fatigue performance) or three-pass grinding where possible, and ensuring that the structural configuration permits easy access for personnel and equipment and facilitates cleaning, draining and drying of tanks.

3.2.5 Where a coating is supplemented by cathodic protection, the coating must be compatible with the cathodic protection system.

3.3 Coating selection

3.3.1 In the selection of a coating for use in ballast tanks the following should be taken into account:

- Service conditions and planned maintenance.
- Frequency of ballasting/deballasting operations.
- Location of tank relative to heated surfaces.
- Required surface condition.
- Required surface cleanliness and dryness.
- Whether cathodic protection is to be fitted.
- Requirements of IMO Resolution MSC.215(82), *Performance Standards for Protective Coatings*.

3.3.2 Coatings intended for use underneath solar heated decks or on bulkheads forming boundaries of heated cargo or fuel oil spaces should be able to withstand constant or repeated heating without becoming brittle or subject to a loss of adhesion. Due regard should be given to the possible poor edge covering properties of hard coatings with a high solid content.

3.4 Initial preparation

3.4.1 Tubular scaffolding should not mask surfaces to be coated. Where contact is necessary, spade ends should be used.

3.4.2 Staging should afford easy and safe access to all surfaces to be coated.

3.4.3 Tubular scaffolding should be plugged or capped prior to blast cleaning to prevent the ingress of grit and dirt.

3.4.4 Staging should be designed to allow thorough cleaning.

3.4.5 Staging layout should be such that ventilation is not rendered ineffective.

3.4.6 Care should be taken when removing scaffolding in order to keep damages to a minimum. Any damages should be repaired in accordance with the paint manufacturer's recommendations.

3.4.7 External surfaces of pipelines which will be covered by pipe clips should be blasted and coated prior to fitting.

3.4.8 Pipeline exteriors should be blasted and coated at the same time as the lowermost parts of the tank. Any over-blast or over-spray affecting surrounding areas should be repaired.

3.4.9 Lighting during blasting and painting must be electrically safe and provide suitable illumination for all work.

3.4.10 Powerful spotlighting must be provided for inspection work.

3.4.11 Adequate ventilation during application and drying of all paints is essential.

3.4.12 Flexible ventilation trunking should be used to allow the point of extraction to be reasonably close to the applicator.

3.4.13 The ventilation system and trunking should be so arranged that 'dead spaces' do not exist. Ventilation must be maintained during application and continued whilst solvent is released from the paint film during drying.

3.4.14 The ventilation system must prevent the vapour concentration exceeding 10 per cent of the lower explosive limit (or less than this if required by Regulations).

3.4.15 For coatings containing organic solvents, during the drying period an adequate number of air changes must be effected, depending on the type of coating being used. This ventilation should be maintained for at least 48 hours after the application of the system.

3.5 Surface preparation

3.5.1 Good surface preparation is one of the most important factors governing the performance of a coating. If contaminants such as oil, grease, dirt and chemicals are not removed from the surface they will prevent the adhesion of the coatings. Soluble salts on the surface may lead to osmotic blistering in the coating. Rust left on the surface will loosen, resulting in a loss of adhesion and if mill scale is not completely removed it will cause accelerated corrosion.

3.5.2 Good surface preparation roughens the surface and enables a good mechanical bond to be achieved.

3.5.3 The surface preparation for coatings should be in accordance with the coating manufacturer's specification. All oil and grease is to be removed from the surface with suitable solvents prior to blast cleaning.

3.5.4 All welded areas and attachments are to be given special attention for the removal of welding flux and weld spatter. Sharp edges should be smoothed and any surface irregularities, including rough weld caps and slag, together with rough edges, fins and burrs, should be mechanically treated using power wire brushing, grinding or chipping, as appropriate.

3.5.5 Only dry abrasive blast cleaning techniques are to be employed and the conditions under which blast cleaning is carried out should preclude condensation. In this respect blasting should not normally be carried out under any of the following conditions:

(a) The surface temperature of the steel is less than 3°C above the dew point.
(b) The relative humidity is above 85 per cent.
(c) When there is any possibility that the surface of the steel is wetted before the first coat is applied.

3.5.6 The compressed air supply used for blasting is to be free of water and oil and adequate separators and traps are to be provided. Prior to using compressed air, the quality of the air downstream of the separator should be tested by blowing the air on to a clean white blotter or cloth for two minutes to check for any contamination, oil or moisture. This test should be performed at the beginning and end of each shift and at not less than four-hour intervals. The test also should be made after any interruption of the air compressor operation. The air should be used only if the test indicates no visible contamination, oil or moisture. If contaminants are evident, the equipment deficiencies should be corrected and the air stream should be retested.

3.5.7 Accumulations of oil and moisture are to be removed by regular purging of the system. Air compressors should not be allowed to work at temperatures in excess of 115°C.

3.5.8 The abrasive used for blasting should be dry and free from dirt, oil or grease and suitable for producing the standard of cleanliness and profile specified. Additionally any organic or water soluble matter should be a maximum of 0,05 per cent by weight.

3.5.9 Iron or steel abrasives are not normally recommended for *in-situ* open blasting. If used, careful and thorough cleaning must be carried out to remove all traces of abrasive from the surface.

3.5.10 Although not recommended, recycled grit may be used providing it is correctly graded, dry and free from dirt, oil, grease, organic or water soluble matter. Recirculated grit should be checked for the presence of oil by immersing a sample in water and examining for oil flotation. Tests should be made at the start of blasting, and every four hours until the end of blasting. If compressor operations are interrupted for longer than five minutes, the air supply should be retested prior to use. If oil is evident, the contaminated abrasive should be cleaned or replaced. All surfaces blasted since the last successful test should be completely reblasted.

3.5.11 The amplitude of blast profile from trough to adjacent peak depends upon the type of coating to be applied. The amplitude should be not more than 50 μm for coatings of the zinc silicate type and not more than 75 μm of the high build coatings. A procedure to measure the surface profile of abrasive blast cleaned steel on site is given in NACE RP 0287.87. The technique utilises a tape that replicates the surface profile and the thickness of the tape is then measured using a micrometer.

3.5.12 Generally, where the final dry film coating is 125 μm or less, it should be in accordance with ISO 8501-1Sa3 or an equivalent standard, i.e., the surface is to be cleaned to white metal such that a uniformly metallic, slightly roughened surface is produced, completely free from foreign matter. Shadowed areas may only be accepted if they are due to differences in the structure of the steel or to a blast cleaning pattern. It should be noted that the possibility of achieving a uniform standard of Sa3 throughout the tanks is remote and a more realistic achievement would be somewhere between Sa2$^1/_2$ and Sa3.

3.5.13 The standard of surface preparation for the majority of the coatings is to be at least in accordance with ISO 8501-1 Sa2$^1/_2$ or an equivalent standard, i.e., the blast cleaned surface is to consist of at least 95 per cent cleaned bare steel and not more than 10 per cent of any single 25 mm square of the surface area is to be discoloured by areas of rust stain or mill scale residues.

3.5.14 In cases where the substrate is corroded or pitted it may be necessary to fresh water-wash the areas after abrasive blasting, then reblast, in order to ensure complete removal of soluble corrosion products.

3.5.15 No acid washes or cleaning solutions are to be used on metal surfaces after they have been blasted. This includes inhibitive washes intended to prevent rusting.

3.5.16 Any sub-standard areas should be identified and must be brought up to the specified standard. Grease free chalk should be used to identify sub-standard areas and it should be removed after the sub-standard areas have been rectified.

3.5.17 After blast cleaning, all surfaces are to be freed of abrasive and dust by:
(a) blowing with dry compressed air; or
(b) vacuum cleaning.
To confirm that the blasted surfaces are sufficiently dust-free to allow successful coating, they shall be tested in accordance with ISO 8502-3 or an equivalent standard, to an extent and with acceptance criteria defined by the coating manufacturer.

3.5.18 Where surfaces have been coated with a prefabrication primer, they are to be similarly cleaned before application of the coatings. If there is extensive breakdown of the primer, the surface affected is to be reblasted.

3.5.19 Since fresh blast cleaned surfaces are subject to immediate corrosion, particularly in areas of high humidity or in a marine atmosphere, it is essential that all cleaned surfaces are coated within four hours of cleaning. In any case the surfaces are to be coated prior to the end of the working day and before any visible rusting occurs, unless humidity can be maintained overnight at a low level.

3.5.20 Checks on the steel surface cleanliness and roughness profile should be carried out at the end of the surface preparation and before the application of the primer and in accordance with the manufacturer's specifications.

3.5.21 Where abrasive blast cleaning is demonstrated to be impracticable at specific locations, alternative mechanical surface cleaning techniques may be applied. In such circumstances, the surface cleanliness should be in accordance with ISO 8501-1 St3 or an equivalent standard and particular attention must be given to ensuring that the surface profile and soluble salt concentrations are in accordance with the coating manufacturer's specification.

3.6 Coating requirements

3.6.1 The composition of any primer used to coat steel after surface preparation and prior to fabrication must be such that it will have no significant deleterious effect on subsequent welding work.

3.6.2 The coatings are to be compatible with any prefabrication primer used and suitable for the intended application.

3.6.3 Materials are to be delivered in original containers with labels intact and the seals unbroken. Containers are to be kept in a safe, clean, well ventilated storage space.

3.6.4 Before use, coatings are to remain unopened in the original containers. Covers are to be kept on opened coating containers when not in use. Coatings are to be used in strict date order and not stored longer than six months unless permitted by the paint manufacturer.

3.6.5 The coating manufacturer's instructions are to be followed for storage, mixing, thinning and application of coatings along with the recommended time limit between coats and health and safety precautions. Only the thinners recommended by the manufacturer are to be used to thin coatings.

3.6.6 Coatings are to be mixed immediately prior to application. All coating materials are to be thoroughly mixed to give a homogeneous liquid without pigment settling out during application. Mechanical mixers are to be used for all coating mixing operations. The entire contents of the coating container are to be used in mixing to ensure the correct proportion of the base coat and pigment.

3.6.7 Coating material which has livered, discoloured, gelled, or otherwise deteriorated during storage is not to be used. Thixotropic materials which may be stirred to obtain normal consistency may be acceptable.

3.6.8 For coating materials requiring the addition of a catalyst, the pot life under application conditions is to be clearly stated on the label, and this pot life is not to be exceeded. When the pot life limit is reached, the spray pot is to be emptied, material discarded, and new material mixed.

3.6.9 Specification and data sheets on the coating materials are to be available at all times.

3.7 Coating application

3.7.1 The application of a coating should be a well planned activity, integrated in the yard's construction plans and carried out under controlled conditions to avoid conflicts with other yard operations.

3.7.2 Coatings should be applied in controlled humidity and surface temperature conditions to surfaces which have been blast cleaned to the coating manufacturer's recommended standard and immediately coated with a compatible prefabrication primer or applied after blast cleaning if this is permitted by the specification.

3.7.3 Areas where the prefabrication primer is damaged in any way may be touched up in accordance with the manufacturer's specifications.

3.7.4 Each coating layer should have the maximum/ minimum thicknesses in accordance with the coating specification. Generally, an 80/20 practice may be adopted which means that 80 per cent of all thickness measurements should be greater than or equal to the nominal dry film thickness (DFT), and none of the remaining 20 per cent is below 80 per cent of the DFT. In the case of tanks (and especially ballast tanks), consideration should be given to adopting a 90/10 practice, which means that 90 per cent of all thickness measurements should be greater than or equal to the nominal DFT, and none of the remaining 10 per cent is below 90 per cent of the DFT.

3.7.5 All paints should be applied by airless spray except for stripe coats where brushes or, if recommended by the coating manufacturer as a preferred option, rollers may be used.

3.7.6 Conventional spray may be used for the spraying of zinc silicate tank coatings.

3.7.7 Efficient mechanical stirrers for the correct mixing of paint should be used.

3.7.8 The spray equipment should comply with the paint manufacturer's recommendations. Adequate moisture traps should be fitted where appropriate so that water or oil can be continuously bled off from the air supply.

3.7.9 Lines and pots are to be thoroughly cleaned before using different materials.

3.7.10 With the possible exception of wet blast primers and moisture cured products, coatings should not be applied to damp surfaces and the specification should stipulate that coatings are not to be applied to surfaces where the relative humidity of the atmosphere is such that:
(a) condensation is present on the surface; or
(b) it will affect the application or drying of the coating.

3.7.11 No coating is to be applied if the temperature is below that specified by the coating manufacturer and, in general, the metal surface temperature should be at least 3°C above the dew point before painting is commenced. The temperature, dew point, and relative humidity should be determined with a sling psychrometer. Suitable procedures are given in ASTM E337. Readings are required at the start of work and every four hours.

3.8 Coating thickness

3.8.1 Generally, high duty coatings should be applied in at least two coats, however, 'wet-on-wet' application may be considered as a two coat system provided:
(a) there is a time interval between the coats; and
(b) there is adequate attention to difficult areas such as welds, edges and any other changes in section and that the recommended coating thickness is achieved over all the structure.

3.8.2 Where coatings other than the zinc silicate type have been accepted as a single coat application then all welds, edges and any other changes in section may require a stripe coat to be applied.

3.8.3 Successive coats should preferably be of different colours or with a significant shade variation to give contrast and ensure complete coverage of the surface, *see also* 3.2.3.

3.8.4 All surfaces are to receive the full thickness specified as a minimum. Areas with inadequate coating thickness should receive additional compatible coats until the specified coating thickness is attained. Coatings are to be brushed on to all areas which cannot be properly coated by spray.

3.8.5 Care should be taken to avoid an excessive coating thickness as this could lead to serious consequences, such as solvent and thinner retention, film cracks, gas pockets, etc. Wet coating thickness should be checked during application.

3.8.6 Each coating layer should be adequately cured before application of the next coat, in accordance with coating manufacturer's recommendations. Intermediate coats must not be contaminated with dirt, grease, dust, salt, over spray, etc. Job specifications should include the dry-to-re-coat times given by the manufacturer.

3.8.7 Thinners should be limited to those types and quantities recommended by the manufacturer.

3.9 Inspection and repair

3.9.1 Wet film thickness checks should be made as the work progresses, using appropriate thickness gauges.

3.9.2 Dry film thickness determinations should be carried out on all significant areas using suitable gauges. (The simple pull-off type gauges are not considered sufficiently accurate for this work).

3.9.3 The full number of coats specified should be applied and the specified film thickness achieved.

3.9.4 All coatings should be free of pin holes, voids, bubbles and other 'holidays'. Holiday testing should be carried out using a suitable 'holiday detector' set at an appropriate voltage for the coating system.

3.9.5 Any defective areas are to be marked up and appropriate repairs effected. All such repairs are to be rechecked for any uncoated areas.

3.9.6 A daily log of the following is to be prepared:
(a) Air and steel temperatures.
(b) Relative humidity.
(c) Paint thicknesses measured.
(d) Extent of coating.
(e) Any other relevant information.

3.9.7 Damage to coatings is to be repaired by cleaning back to a sound base, recoating the affected areas as required in the specification and feathering to tie with adjoining areas. Prior to the application of any coating, all damage to previous coats is to have been repaired.

3.9.8 The area to be cleaned is to be carried over onto the firm surrounding coating for not less than 25 mm all round the edges. These are to be feathered by a suitable method to ensure continuity of the subsequent repair coating.

3.9.9 Areas with inadequate coating thickness are to be thoroughly cleaned and, if necessary, abraded and where applicable additional coats applied until the specification is complied with. These additional coats are to blend in with the final coating at adjoining areas.

3.9.10 Where welding has to take place on coated areas, unless they are approved prefabrication primers, the coatings are to be removed locally and the surface after welding is to be prepared and recoated in accordance with the recommended procedures.

3.9.11 When dry film thicknesses are less than those specified, additional coats are to be applied as necessary to achieve specified thickness. For inorganic zinc silicate, areas of low film thickness should not be repaired by additional coats. In this case the coating is to be removed and the area re-coated to the specified thickness.

3.10 Safety aspects

3.10.1 It should be noted that paints, coatings and thinners are potentially hazardous from health and safety points of view if not strictly controlled in accordance with good practice. Detailed advice on the safe working practices to be followed should be obtained from the relevant governmental safety agencies.

3.11 Maintenance

3.11.1 Maintenance of the corrosion protection system should be included in the overall maintenance schemes.

3.11.2 The most efficient way to preserve the corrosion protection system is to repair any defects found during the in-service inspections (e.g., spot rusting, local breakdown at edges of stiffeners, etc.).

3.11.3 During maintenance hard coatings should be restored using the type originally applied or by a compatible hard coating recognised by LR. The compatibility of coatings should normally be agreed by the paint manufacturer, and the coatings should be applied in accordance with the manufacturer's requirements.

3.11.4 The restoration of the damaged hard coatings by compatible coatings not recognised by LR will be accepted, provided such coatings are applied and maintained in accordance with the manufacturer's specification. Details of such coatings are to be reported for information and record purposes.

3.11.5 If the required conditions for the application of the original coating are not achievable, a coating more tolerant of a lower quality of surface treatment, humidity and temperature conditions may be considered, provided that it is applied and maintained in accordance with the manufacturer's specifications.

3.11.6 Currently there are numerous non-oxidising soft coatings which are being marketed for the purpose of repairing hard coatings. Proposals to use this type of coating, including the manufacturer's confirmation of their compatibility with the existing coatings, are to be referred for consideration.

3.11.7 It should be noted that soft coatings are, in general, not suitable for use in association with cathodic protection.

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